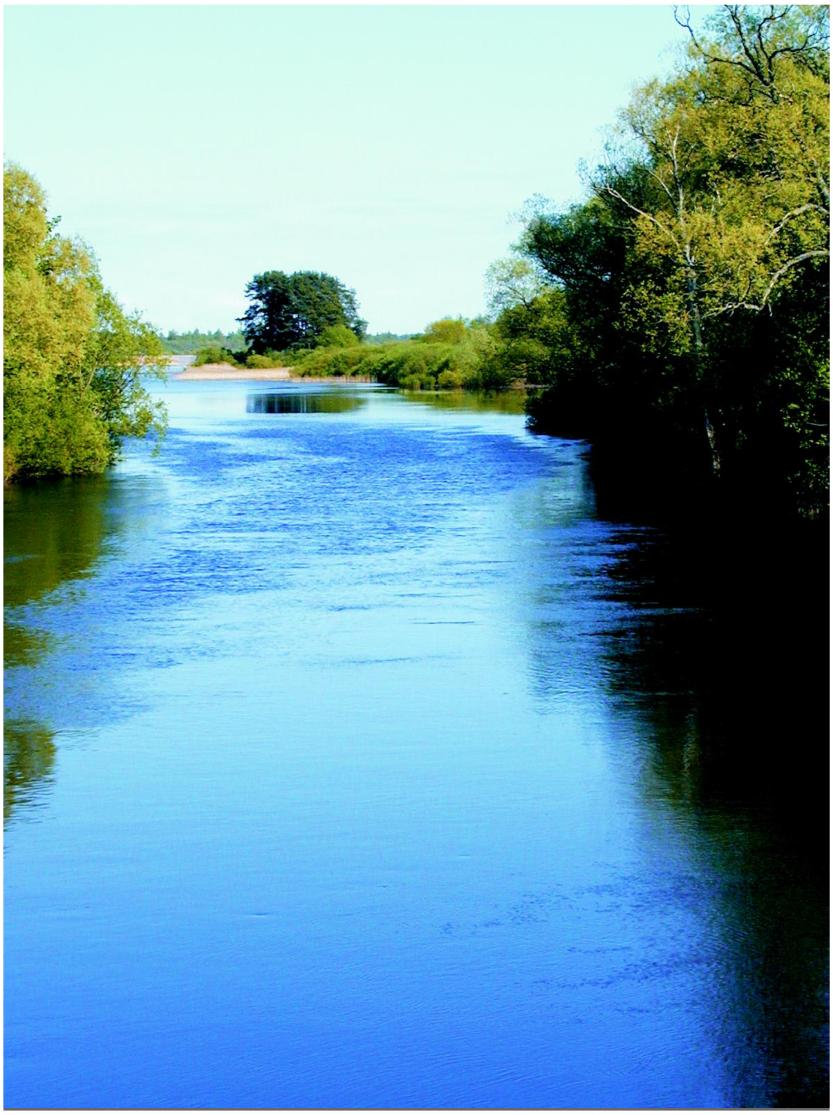
The Finnish Environment 793

ENVIRONMENTAL PROTECTION

Tom Frisk, Māris Kļaviņš, Uldis Bethers, Ilga Kokorīte, Juris Seņņikovs, Valery Rodinov and Ämer Bilaletdin

Loading from Latvia and its impact on water quality



PIRKANMAA REGIONAL ENVIRONMENT CENTRE

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Foreword

We are now delivering results of a joint Finnish–Latvian project supported by Maj and Tor Nessling Foundation. The aim of the project was to develop an interdisciplinary view on the factors affecting water quality in Latvia, but also influencing the Baltic Sea. So, we have tried to integrate not only analysis of socio-economic situation in Latvia and actual human impacts on water quality with process of development of environmental protection system, but also possible responses of aquatic systems and loadings to the Baltic Sea focusing on the influences coming from cities of Latvia, with the modelling approach. Research on these aspects is in continuation. At the same time, another goal of this project was to summarize existing information on environmental quality, environmental protection system in Latvia during last decades – transition period and on how the historical heritage and the restructuring process in society has influenced environment and how these activities can influence the development in future.

To reach these aims scientists with different background have been involved – geographers, environmentalists, biologists from Department of Environmental Science of the University of Latvia, modellers from the Faculty of Physics and Mathematics of the University of Latvia and from Pirkanmaa Regional Environment Centre. So, as result of this project we find development of understanding of the complexity of environmental problems related to surface water quality and further need in cooperation to implement major results of the project. We hope that this project may result in development of new tools for river basin and city loading management.

We would like to acknowledge all those who have supported the success of the project – Mr Jari Rauhala about his management of the project running, Mr Česlavs Kuļikovs for his help, Ms Anu Peltonen for her editorial work, Mr Heikki Kaipanen and all those who have been met during the work at the project, and, of course, Maj and Tor Nessling Foundation.

Tampere, August 10, 2005

Tom Frisk Māris Kļaviņš

Contents

Introduction

Environmental problems now are among the most important questions for states of different stages of economical development, social and political systems. The most often expressed view concerns the recognition or understanding of human impacts on nature and environmental quality in cities. Commonly it has been assumed that environmental problems are especially urgent for East European, Baltic countries and the former Soviet Union (Medvedev 1990, Feshbach and Friendly, 1993, Eckerberg 1994). However, there exist major differences among different states in this region, depending on the level of industrialization, the amount of resources consumed and some other factors. Depending on these factors, as well as, on the way of development, different attitudes towards environmental issues and the ways of solving them in relevant economical and political situation have been pointed out.

The key concept for understanding of processes in each country lies in the term: ***transition*** - transition from one political economical system to another. Transition from one social, political and economical system to another, restructuring of production is of principal importance to reach progress. Transition, as such, is an essential part of any development, including processes in society. At present many states in America, Europe, Asia and Africa are in the transition state. The transition process in Eastern Europe and Baltic countries is characterized by a transition from a centrally planned to a market economy and from authoritarian to democratic regimes. This transition process has got common features which are typical for nearly all postsocialist countries and it has got diverse features in different processes in society, production and the environment of these countries.

Of principal relevance is the impact of the transition period on environmental quality, environmental protection system, human environment and environmental quality in cities in Latvia, as one of countries in Eastern Europe. On the other hand, the policy carried out in environmental protection area influences the restructuring process in society. The transformation process of the society in Latvia raises questions of possible development models towards progress. At the same time it must be stressed that common models of development cannot be applied to study processes in cities. There is abundant literature on environmental problems, but very little on that what happens with environment in cities during the transition process. Especially it is important to select development models of cities in relation to sustainable development. At the same time some negative aspects of the transition process are evident. Recent level of understanding of environmental problems and their international character determine the priority of environmental issues among other problems which must be considered when restructuring the society. Yet, even more relevant these questions are when we look at these problems from the point of view of development processes in cities. In this respect the openness and efficiency of aims and decisions regarding environmental problems and capacities to solve them in cities can be considered as indicators of society's ability to changes. This aspect is still more essential when considering the aggravation of environmental problems in urban regions.

At the same time Latvia has a tendency to develop according to Western way of development (intensive development of agricultural and industrial production, exhaustive use of non-renewable resources), thus on this way Latvia faces many drawbacks which are not so easy to be overcome. So, in the process of society restructuring it is possible to include ideas of sustainability. The best known definition of sustainable development is set out in the Bruntland Report (World Commission on Environment and Development 1987): “Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs“. Equity issues are integral to concept of sustainability, including interpersonal equity (between individuals), interregional equity (between regions and States) and intergenerational equity (between generations). Thus, the environmental situation and environmental policy in cities can be considered as a key factor influencing environmental quality and overall progress of society in direction towards sustainability.

General description of nature and socio-economical situation in Latvia

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2.1. Physico-geographical description of Latvia

The territory of Latvia covers 64 589 km^2. Maximal extensions are from north to south - 210 km and from west to east - 450 km. The length of state boundary is 1900 km out of which the length of coastline is 500 km. The neighboring countries are Estonia, Russian Federation, Belorussia and Lithuania.

The nature and natural conditions of Latvia are determined by its location as part of the vast East-European Plain on the Baltic Sea and in mixed forests zone. The territory under consideration is characterized by a flat surface topography with small absolute and relative heights. 57% of the area are less than 100 m above the sea level, while 40.5% and 2.5% are 100 to 200 m and over 200 m above the sea level, respectively. The average elevation amounts to 87 m above the sea level. The highest point of the area - Gaiziņkalns (311.5 m) - is located on the Vidzemes Upland. The surface of Latvia has been developed by Quaternary glacial and ancient sea sediments and recent exogenous processes have finally formed. The bedrock is located correspondingly deeper under these sediments (from 40-50 m till 200 m). In the topography there dominate hilly highest and slightly undulating plains.

As to the climate it is influenced by air masses coming from the Atlantic Ocean where west winds prevail and it can be regarded as humid. The average temperature is from +16 ˚C till +18 ˚C in July and from -3 ˚C till -7 ˚C in January. Cyclones are typical for Latvia. Average amount of precipitation is 700-800 mm per year. The highest amount of precipitation is in autumn and winter, the lowest - in spring.

The climatic conditions, character of land surface and the amounts of precipitation determine the great role played by inland waters. There are more than 3000 lakes and 12 000 rivers in Latvia. The largest lakes are Lake Lubāns with the area of 82 km^2 followed by Lake Rāzna (58 km^2), Engure (41 km^2) and Burtnieks (40 km^2). The deepest lake is Lake Dridzis (65.1 m). The majority of lakes are shallow (average depth less than 3 m) and great areas of their basins are occupied by wetlands which play a principal role in the water balance. The longest rivers are the River Daugava, the River Gauja, the River Venta and the River Ogre. Bogs occupy 6400 km^2, or 10% of Latvia's area.

The most spread soil type in Latvia is podzolic soils (52%) out of which sod-podzolic soils constitutes 46%. Soils in Latvia can be considered as relatively unpolluted and the heavy metal content is at natural background level. Of the total surface area 39% is agricultural land of which arable land constitutes 26 %.

Latvia is rich in forests, 44% of the entire territory is covered by forests. Coniferous forests are the most widely spread ones. The flora of Latvia includes around 1900 species and there are around 1300 species of animals. The most important wild animals for hunting are wild boar, elk, roe deer, hazel grouse and red grouse.

Considering adverse impacts on biodiversity and many species common for nature the biodiversity in Latvia is higher than in industrially utilized areas of Western Europe. Protected areas in Latvia cover 6.4% of the entire territory of Latvia and they have an important function in conservation of endangered species and existing biodiversity level.

Latvia is not rich in mineral resources. The most important mineral resources are limestone, dolomite, gypsum, sand, gravel and clay, which are connected with the production of construction materials. Peat can be regarded as important resource being of energetical significance for economy, too.

2.2. Economical development of Latvia

Since 1991, when Latvia regained its independence the government has implemented reforms the most important of which are currency reform and the introduction of a liberal currency regime, tight monetary and fiscal policy, several systematic transformations aimed at stimulating privatization process, thus, decreasing the role of the government in national economy.

At the initial stage of economic reform (1991-1992) a dramatic fall was observed in the development of national economy, the lack of stability in the financial area, almost hyperinflation. The standard of living of population was also rapidly decreasing.

The reforms of further years (1993-1994), the tight monetary and fiscal policy implemented by the Government and Bank of Latvia allowed to gradually stabilize the general status of national economy. In 1994 for the first time after regaining its independence Gross Domestic Product (GDP) did not decrease and even slightly grew.

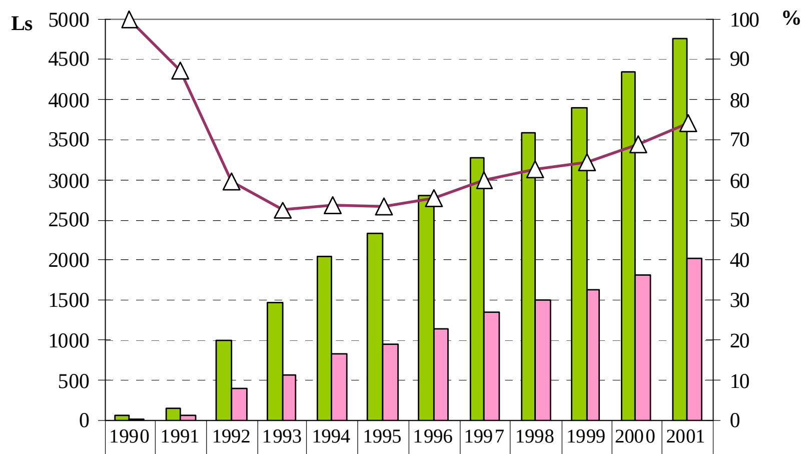
Currently, the base level of macroeconomics stability has been achieved in the state: relatively low level of inflation, comparatively small budget deficit and an equilibrated balance of payments. Results of macroeconomic stability have been positively evaluated by international economic institutions.

It must be noted that activities of macroeconomic stabilization particularly in the first years of reforms have acted not only in the positive direction. The increase of rate of national currency against foreign currencies and a rapid fall of inflation has negatively affected economic activity especially, in the sphere of production.

The goal of the fiscal policy implemented in Latvia is to secure a balanced economic growth and fiscal stability. Since 1996, with the exception of 1999 when financial crisis in Russia occurred, the fiscal deficit of the general government budget was lower than identified in the Maastricht Treaty (3% of GDP). After Latvia's joining the EU the requirements of Maastricht Treaty must be fulfilled.

Structural reform is proceeding at a slow pace, privatization of medium size and big state-owned companies has been in process for several years. The result is that state property is still important in the structure of industrial production (Ministry of Economy, Republic of Latvia 2001).

In the first years of reforms (1991-1993) according to the data of Central Statistical Bureau GDP fell by approximately 50% compared to 1990 (Fig. 2.1.).



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Actual prices, mln. Ls	62	143	1005	1467	2043	2329	2807	3269	3592	3890	4348	4759
GDP per capita, Ls	23	54	384	572	810	937	1142	1344	1491	1627	1832	2021
GDP, %	100	87.4	59.3	52.6	53.7	53.2	55.2	59.8	62.6	64.4	68.8	74.1

Figure 2.1. Trend in GDP (1990=100%) (Central Statistical Bureau…2004).

Implemented reforms and integration in EU have had a positive impact on economic development of the country. In the period from 1996 till 2003 Latvian GDP has grown on average by 6.1% annually (Ministry of Economics 2004) and it is among the highest rates in Europe. High domestic demand and the ability of Latvian enterprises to find new export markets was the reason for the growth of GDP over the past years. The main contributors to that were manufacturing, construction, trade, commercial services, transport and communications (Ministry of Economics 2004).

The decrease of inflation of consumer prices from the level close to hyperinflation i.e. 958.6% was achieved (December versus December) in 1992 to 26.3% in 1994. Since 1998, consumer price inflation level was within limits of 2-3%, but in year 2004 inflation rise was observed due to the rise in government-set prices, higher import prices, increased taxes and joining EU.

Latvia conducts foreign trade transaction with more than 120 countries. Latvia exported its commodities to 85 and imported from 112 countries. The EU is the main trading partner of Latvia and trade with EU member states is constantly increasing, and at the moment, including also new member states about 80% of total exports and imports are linked with EU (Ministry of Economics 2004).

During the last decade both export and import was grown rather rapidly (Fig. 2.2). However import has increased more rapidly than export and since 1994, foreign trade balance of Latvia has been negative. In 2003, the dominance of import over export comprised more than 1300 mln LVL (Central Statistical Bureau…2004).

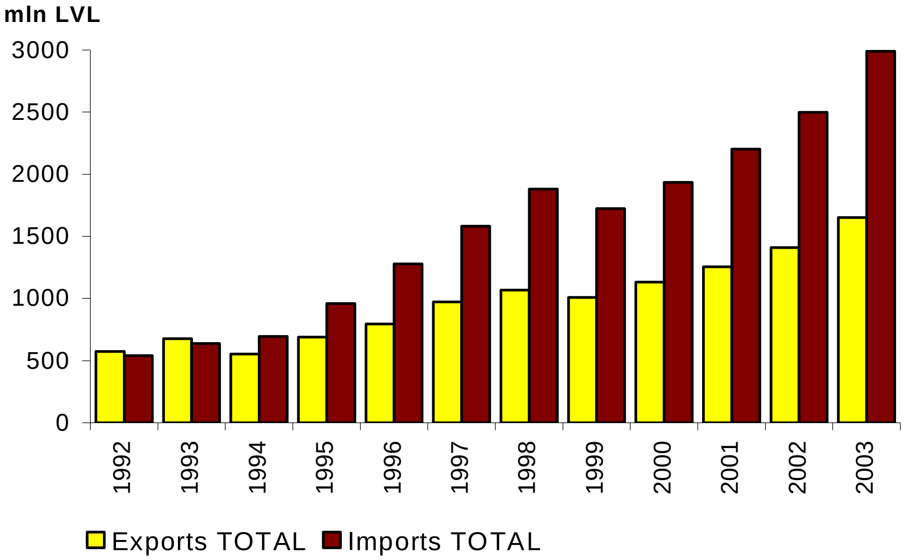


Figure 2.2. Changes of total exports and imports, 1992-2003 (mln LVL) (Central Statistical Bureau…2004).

The most profitable export items for Latvia over the last years has come from wood industry, metal processing and machine building, which comprised respectively 35.2% and 21.7% from the total export in year 2003. Textiles and textile articles, food products and chemical goods are also of importance (Fig. 2.3.). In 2003 exports grew in all categories of goods, but the biggest growth were recorded in wood industry, metal processing and machine building sectors which contributed respectively 45% and 23% of the total export growth.

Transit services are very important for the national economy of Latvia. They constitute approximately 15% of revenues from Latvian exports of goods (Ministry of Economy 2004).

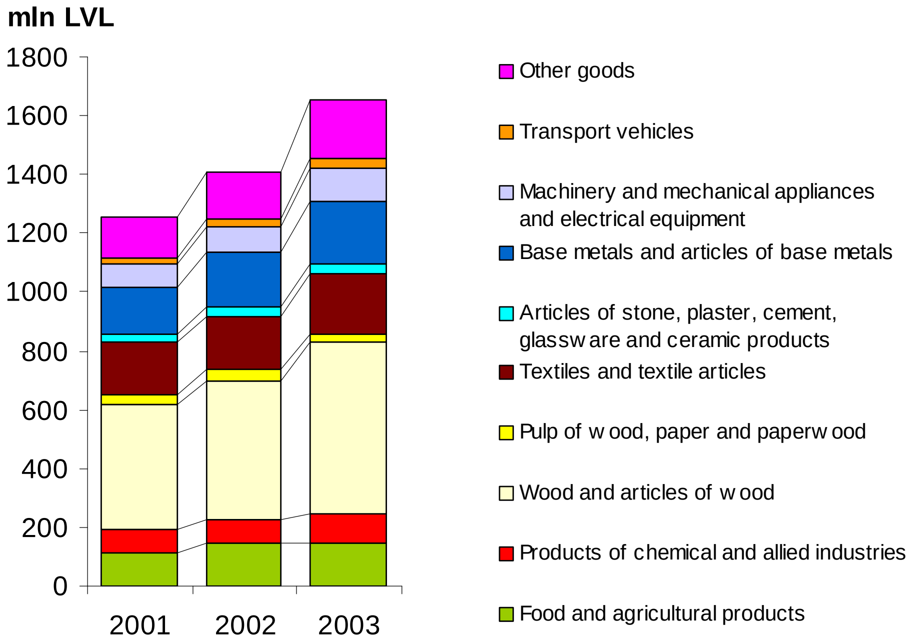


Figure 2.3. Export by main commodity groups.

The most profitable import items for Latvia over the last years have been import of machinery and electrical equipment, products of chemical industry, mineral products and agricultural and food products (Fig. 2.4.).

During the last few years, trading rates have grown both with EU states and CIS countries, proving that several industries are able to compete in the external market. The main trading partners in 2003 were Germany (16% of the total turnover), Lithuania (9% of the total turnover), Sweden (8% of the total turnover), Russia (8% of the total turnover) and the United Kingdom (7% of the total turnover) (Ministry of Economy 2004).

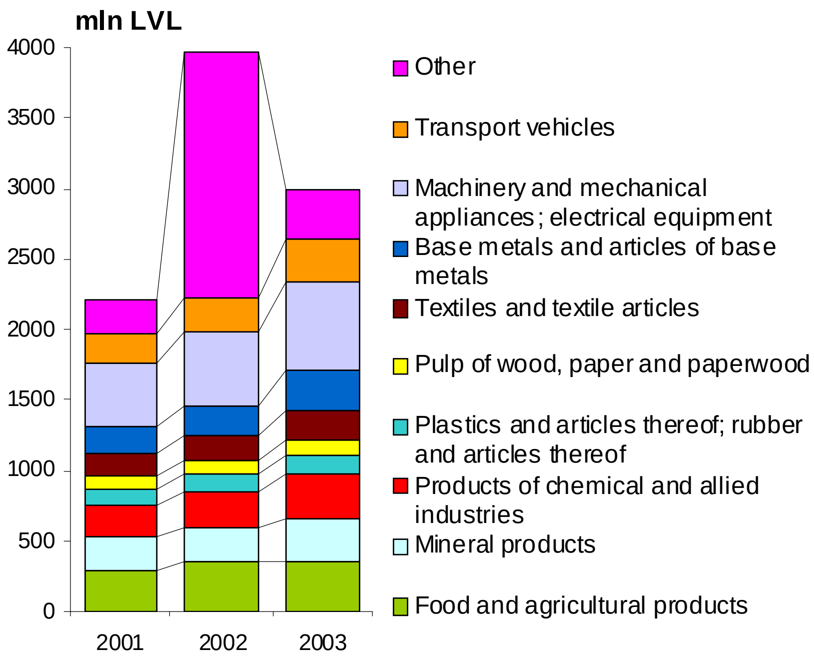


Figure 2.4. Import by main commodity groups.

Real decline in wages for people employed in national economy was stopped in the second half of 1993 when the speed of average wage increase exceeded the growth of consumer prices. In 1995 a new fall in purchasing power of population was influenced by the financial and banking crisis (Ministry of Economy 1995). In recent years permanent growth of real incomes can be observed. Net wages in 2003 in comparison with 1996 had gone up by 89% and by 10.9% exceeded the level of 2002, however, during this period inflation had increased by 51% (Ministry of Economy 2004). According to the Human Development Index (HDI) of the United Nations Development Program Latvia in 2003 is placed in the 50th position in the world according to the standard of living. Yet, growth of income is very uneven and polarisation in terms of income is increasing. Growth of retirement pensions is slower than the growth of salaries (Ministry of Economy 2004).

The self-evaluation of households made in 2003 shows that 7.3% of all households consider themselves poor; in rural areas the figure is 7.2%. 54% of all households considered themselves as neither poor nor rich in the survey of 2003 (57% in rural areas). In 2003, 8.5% of households considered that they were of good welfare (6.6% in rural areas) (Ministry of Economy 2004).

From 1990 till 1993 the production output decreased dramatically, due to this the number of unemployed increased from economically active population from 0.2% at the end of 1991 to 5.9% at the end of 1993. In the middle of 1990s, the level of unemployment is stabilized at the level of around 8 % of the number of economically active population (Fig. 2.5.). However, as proved by some opinion polls and estimates the real level of unemployment in Latvia is much higher. The main features of unemployment are the following:

- High rate of the "hidden" unemployment;
- Approximately 51% of unemployed are women;
- More than half of unemployed are people aged 30-49 and approximately 20% of unemployed are younger than 25 years;
- Approximately 2/3 of unemployed have special secondary and primary or incomplete secondary education, the lowest level is among those who have higher education;
- The speed of retraining and professional education of unemployed has not been adequate;
- The level of unemployment considerably varies in different regions of Latvia, as well as, between the regions and cities. The lowest unemployment rate is in the Rīga region, but the most aggravated situation is in Latgale where unemployment in some regions exceeds 20% of the economically active population.

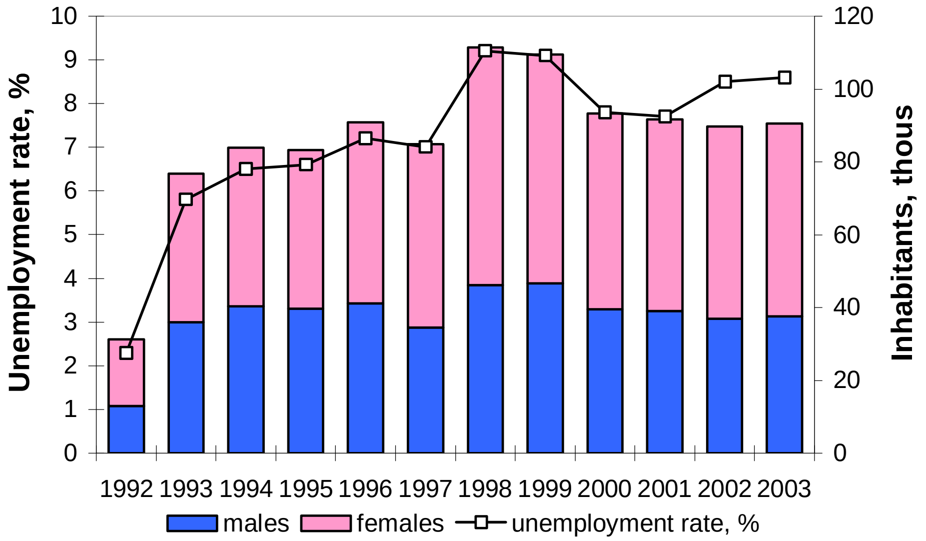


Figure 2.5. Unemployment rate and unemployed by sex.

2.3. Changes in industrial production

The development of Latvia's national economy, industrial production and agriculture has been greatly influenced by both its natural conditions and political situation. From 1945 - 1991, Latvia was an integral part of the national economy of the USSR. This economy was characterized by inefficient management, neglecting of environmental problems and one-sided orientation to both the vast use of raw materials and the needs of the former Soviet market. Some fields of production (energy production) were totally underdeveloped. The most developed branches of industrial production were machine building, food processing, chemical industry and textile industry. The development of Latvia as an independent state totally changed the aims, preconditions and the structure of industrial production. As far as Latvia declared its desire to develop as an open and democratic society, industrial production also has to be restructured according to the demands of free market rules that exert pressure on the existing system of production. The legacy of pollution needs to be overcome. The industrial production in the centrally planned economy was diverted towards heavy industry and energy consumption based on wasteful use of fossil fuel sources. Such sectional specialization, as well as, resource-intensive production technologies and the extraordinary price distortions, which encouraged wasteful consumption, resulted in an economy which used 2-5 times more materials and energy per unit of economic output than in market economies. The negative environmental impacts of such a structure were aggravated by the geographical concentration of industries and population in only a few cities, mostly in Rīga. The next principal problem was to increase efficient utilization of natural resources, balancing the existing desire to develop along with conservationist attitudes in society. The problem of waste management and disposal is of major importance. At the beginning and middle of 1990s, industrial production in Latvia was in deep crisis, due to the following reasons:

- destruction of the Soviet market and an inability of quick entering the Western market;
- the early stage of legal and economic reform in Latvia, unsettled private and state property regulations;
- low technological level of production, old equipment and buildings, underdeveloped infrastructure;
- lack of investments;

- negative attitude to industry in Latvia as a product of the Soviet occupation.

The crisis has resulted in a steep decline of gross domestic product and industrial production (20-35 % per year in 1990-1993). Large transportation and energy costs made production at state owned enterprises uneconomical. On the other hand, adequate legislation and private property rights were not settled. Economical and political relations with Russia, as well as with other republics of the former USSR, were not defined. In 1995, the share of industry in GDP decreased rapidly.

All these processes can be identified as conflicts or constraints between the existing system and structure of production with the newly developing society, regarding its political ambitions, development of the legal system and possible directions of economical development including needs of environmental improvements.

Basic obstacles preventing the development of industry may be subdivided into two groups of problems:

- *First group* of problems is linked with the change of property structure. Private sector was not gained the dominating position in industry of Latvia and the speed of privatization process was not fast enough. Status of a state owned company and its management system did not promote effective and prospective development of the companies. In 1990s the decrease of the share of state property in the structure of industry continued (Fig. 2.6.). There was the growth of the share of mixed property without state capital participation.
- *Second group* of problems comprises short and medium term problems, for example, shortage of markets, domestically and in foreign countries, financial difficulties linked with freezing of funds, unconformity of interest on loans to real payment capacities of companies. Such problems should be basically addressed to the level of microeconomics that is to the level of individual companies.

The crisis in industry started in 1991 and it was connected with changes of political situation in Latvia. It resulted from the necessity to get materials, high cost expanses of electroenergy, distribution of production output and investments. The decline was most sharp in machine building and metal industry, chemical industry, pulp and paper industry, production of construction materials, electronic and radio-electronic industry, light industry.

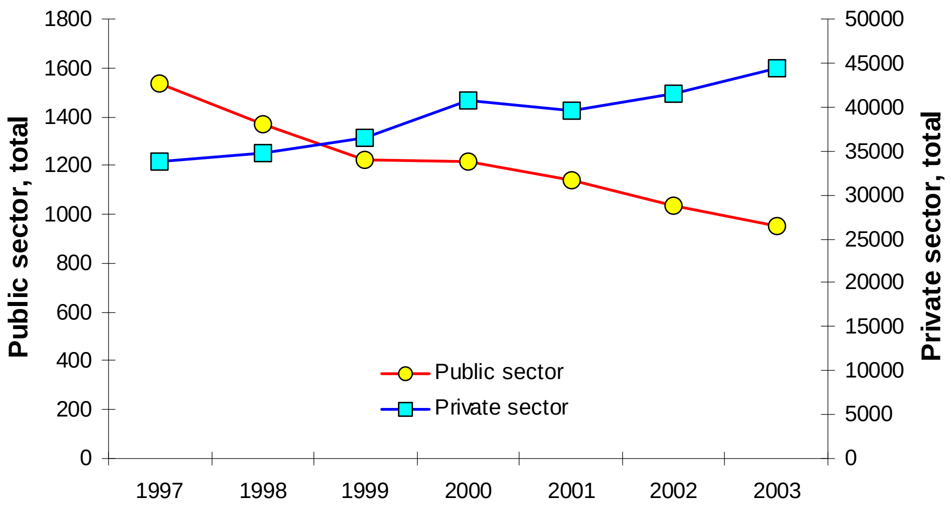


Figure 2.6. Number of enterprises and companies by form of ownership (Central Statistical Bureau…2004).

On the other hand, these industries consumed the most part of raw materials and most of all polluted the environment. So, in Latvia during the early 1990s in the early phase it was possible to see the structural changes in industrial production, which was common for West European countries for the period of 1970-1990. At the same time it proceeded with changes in the general structure of different branches of production which are common for West European countries, namely the increase of different services in the GDP.

The current structure of industry is not changeless and it is characterised by an annual increase of volumes of industrial output (Fig. 2.7.).

The amount of output in the manufacturing sector shows steady growth for several years, having reached annual growth of 9-10% since 2001. In 2003 the highest growth rates were registered in wood industry, machine building and metal processing industries. Growth was mostly encouraged by expansion of exports, which in turn was positively influenced by appreciation of the euro (Ministry of Economy 2004).

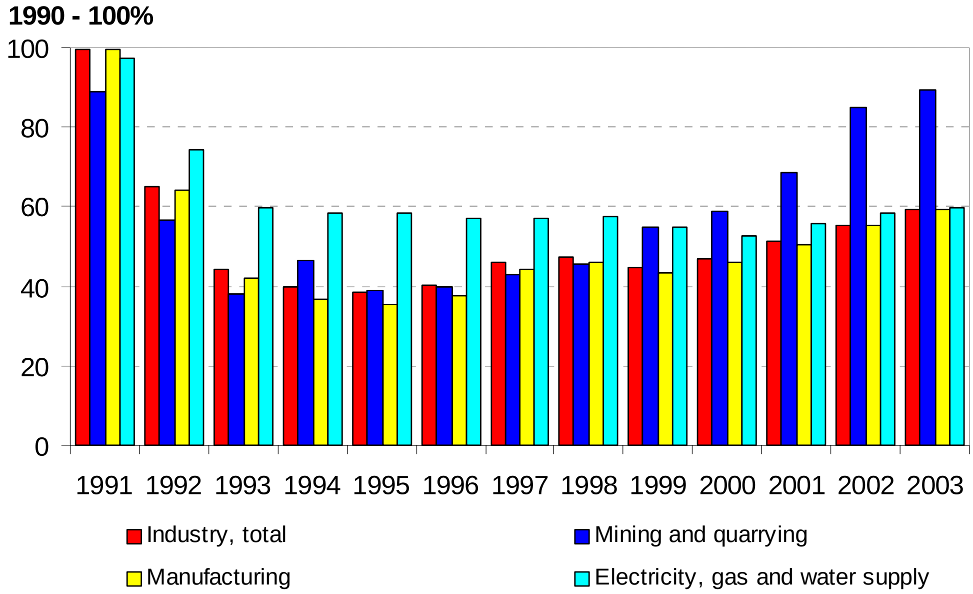


Figure 2.7. Gross industrial output indices at constant prices (1990=100%) (Central Statistical Bureau…2004).

The industrial structure of Latvia is dominated by sectors using cheap labour and natural resources or sectors with a low value added. The value added created in the food industry, light industry and wood industry accounts for more than a half of the total industrial value added.

Energy resources present one of the urgent problems, because Latvia does not have its own significant energy resources, which can ensure the energy needs. In Latvia, both the imported (natural and liquefied gas, oil products, coal) and local (wood and peat) fuels are used to provide fuel and energy. Part of electricity is generated in hydropower plants and thermal power stations, another part is imported. The economy of Latvia is to a great extent dependent on foreign energy resources (Fig. 2.8.). Among the Baltic states, Latvia alone has an unfavorable electric energy balance, with domestic electric energy production covering only half (about 5×10^6 kWh) of the total electric energy demand. Also, the use of energy is inefficient, if compared with West European countries.

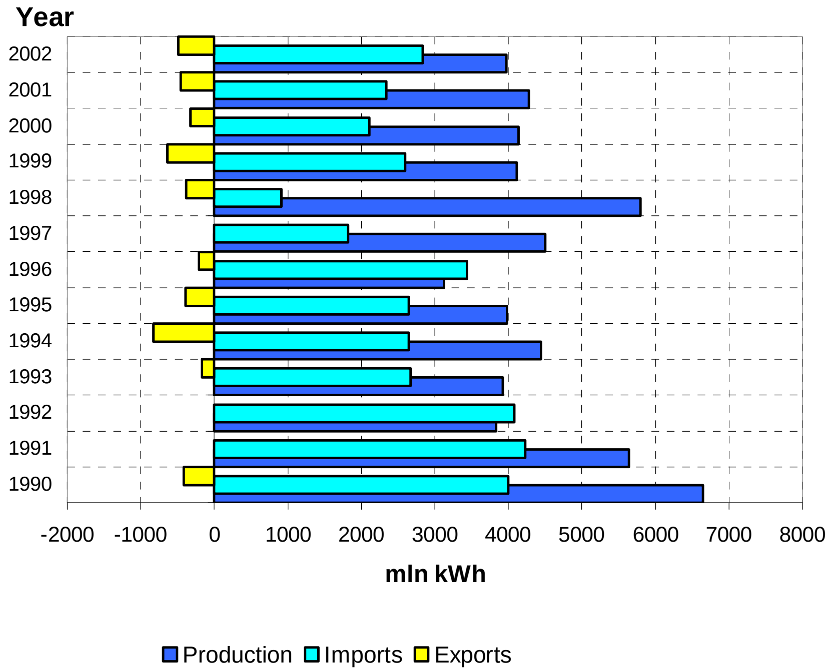


Figure 2.8. Electricity balance in Latvia (Central Statistical Bureau…2004).

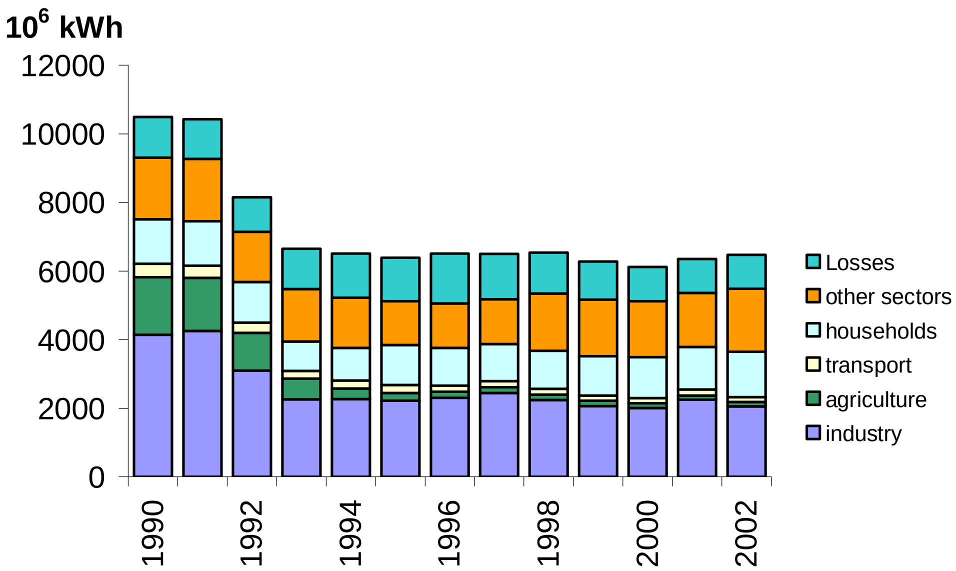


Figure 2.9. Electricity consumption in Latvia (Central Statistical Bureau…2004).

Energy experts in Latvia, with a help of western experts, developed a plan, which proposes the expansion of the Riga thermal electrical power station, building of a new power station near Liepāja, as well as, the development of alternative energy sources. A third Riga thermal electrical power station could be another opportunity.

Industrial sector is the biggest electricity consumer and the electricity consumption within this sector has been quite stable during the last decade (~2200 x 10^6 kWh). Electricity consumption in household has increased during the last few years, yet in agricultural enterprises and peasant farms have decreased (Fig. 2.9.).

A great role is devoted to different energy saving plans. However, lack of financial resources, as well as, environmental considerations, hinder the development of new energy production plants and implementation of energy saving measures, such as improvement of heat insulation, installation of energy measurement devices etc.

2.4. Changes in agricultural production

One of the most important branches of national economy of Latvia is agriculture. In the history of the first Latvian Republic (1918-1940), whose latter years are seen as Latvian agriculture's "golden age", and there is a reason to say that considering economic and social development at that time agriculture was the main branch of economy of Latvia. It was developed because Republic of Latvia did not have natural resources of raw materials but it had good climatic conditions. The agricultural production of Latvia could compete in European market. With the fall of communism it was suggested that agricultural production would soon find its place in the world markets and, thereby, ensure the nation's economical stability.

Now more than 30% of the land fund of Latvia is agricultural. Agriculture in Latvia consists of two main complexes of branches: crop production and livestock breeding. The main cultures are food grain, potatoes and sugar beets (Fig. 2.10.). Livestock breeding is mainly oriented towards to pig and poultry production (Fig. 2.11.). In 1992 The Law on Land Tenure Reform was adopted, which led to revision of the entire management system of agriculture, regulation of land-use relations, and provided conditions for efficient use of land.

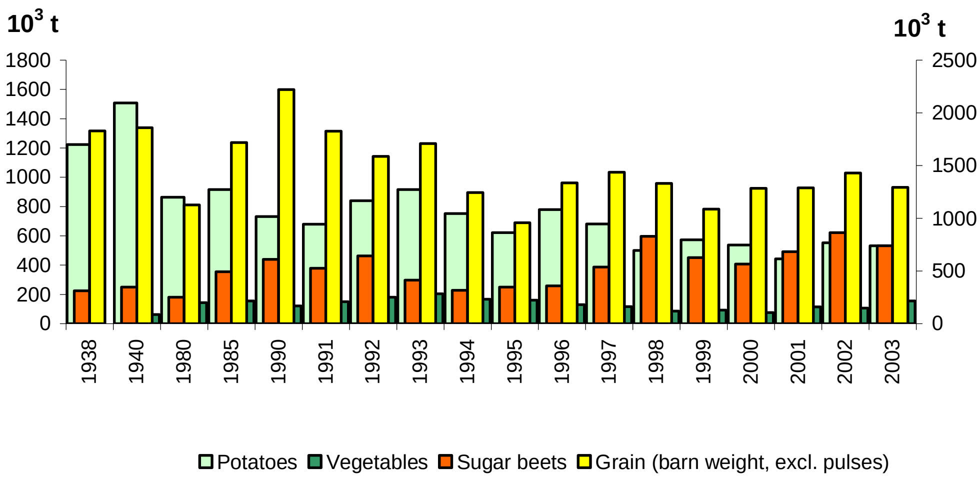


Figure 2.10. Crop production (10^3 t) in Latvia (Central Statistical Bureau…2004).

Since the end of the 1990s, production of meat and milk has stabilised, but production of eggs is slightly increasing (Fig. 2.10.). However, the expansion of agriculture will depend on the adaptation of agricultural production units to EU standards and quality and external demand (Ministry of Economy 2004).

However, agricultural production, similar to industrial, is faced with severe problems in the transition period. GDP of agriculture, hunting and forestry decreased from 11.7 in 1993 to 10% in 2000. The decrease of agriculture volumes of production has led to the following:

- The changes of economical structure and forms of properties destroyed big farms. They had share in smaller private new farms which areas often were too small for efficient agriculture.

- Most part of small farms have problems connected with agricultural machinery. The lack of agricultural machinery does not allow carrying out efficient work, machinery from former collective farms is not efficient for the utilization on smaller areas.
- Small farms have problems how to sell their products. Agricultural development faces the lack of financial means and it is connected with the length of specific reproduction cycle, the interest rates are very high, besides, there is a lack of credits.
- There is a need to look for new markets since the previous market of Russia has been lost. Low quality of produced goods results in poor competition with freely imported goods from other countries;
- Old technology and equipment, low productivity in agriculture: a need to restructure, but there is a lack of financial resources;
- Unsettled legal and economic relations in the rural areas.

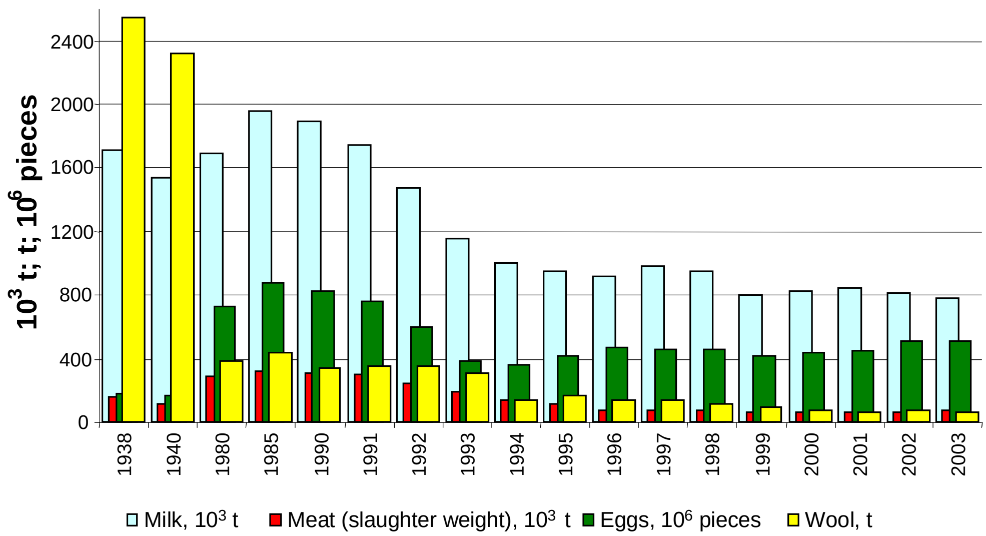


Figure 2.11. Production of principal livestock products (Central Statistical Bureau…2004).

All these conflicts can be regarded as constraints between the old way of production (collective land-use and production) and the new legal and economic systems and method of production in an open free market society.

In following years no rapid decrease is predicted because the number of farms possessing large areas could increase and, besides, it is necessary to find new markets for selling the produce. The volumes of crop production and livestock breeding decreased (Fig. 2.12.). The causes were the following:

- diminished cereals areas;
- low productivity of potatoes;
- decreased amount of livestock.

These conflicts resulted in a sharp decrease of agricultural output. Over the last years the development of agriculture was determined by many closely interrelated factors in structure. To change structure of production, peasants' farms need machinery, production resources and buildings, and find market. Currently, economical situation of Latvia can not afford to accumulate so many financial resources, besides, there is a lack of efficient management system which hinders the development of agriculture.

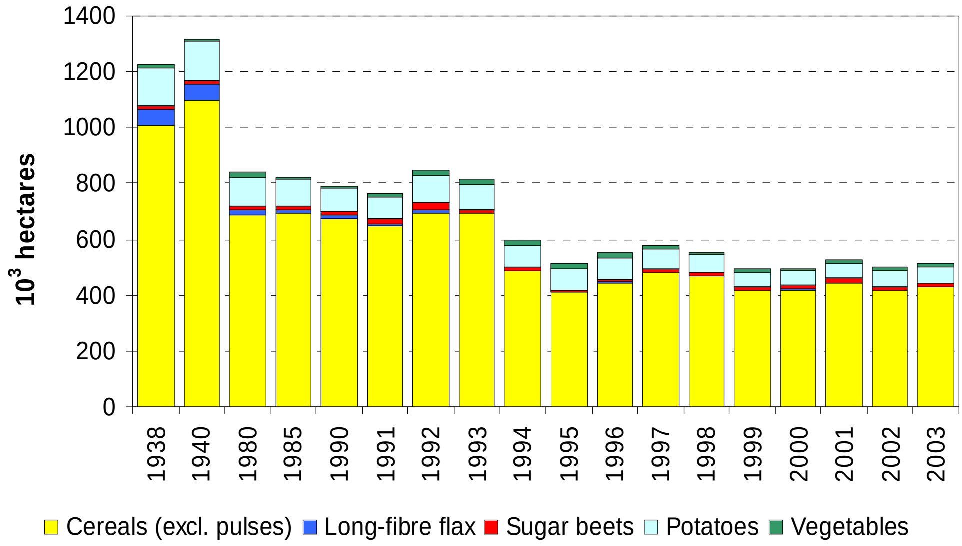


Figure 2.12. Sown area of agricultural crops (10³ ha) (Central Statistical Bureau…2004).

Recession in agricultural production and structural changes in Latvia also have an adverse impact on agricultural habits and so, for example, during the beginning of 1990s the use of fertilizers and the liming of soils has in principle decreased.

Since year 2000, the increase in use of mineral fertilisers and liming of soils and also slight increase in use of pesticides and plant protection products is observed (Fig. 2.13.).

The promotion of a cleaner production, changes in technology and restructuring of production to an environmentally more sound one present the most important aims of environmental policy, which could lead to the reduction of major pollutants, and the improvement of the working environment.

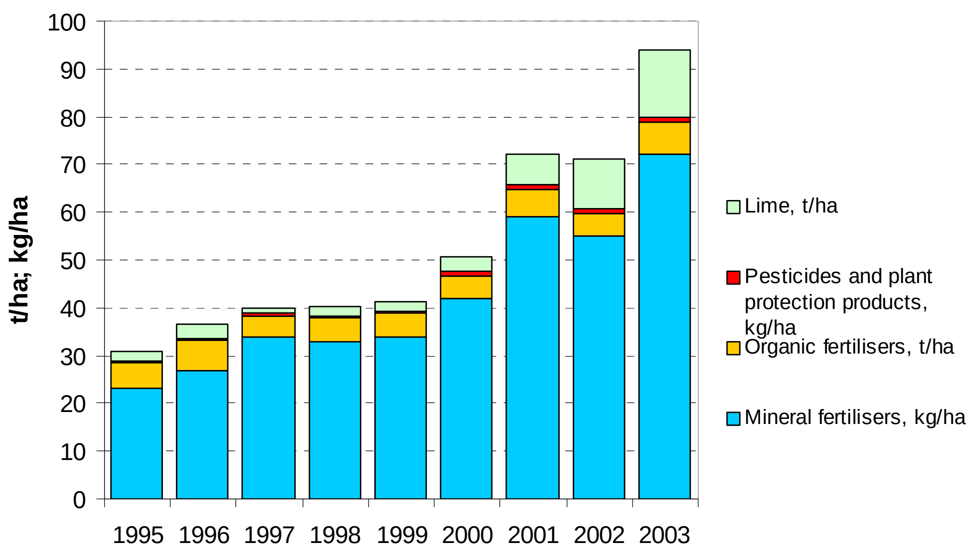


Figure 2.13. Use of fertilisers, limes and plant protection products (Central Statistical Bureau…2004).

These aims could be related both to industrial and agricultural production. At the same time, the promotion of a cleaner technology is the mechanism how to implement environmental policy. These questions are especially relevant in Latvia, where industrial production typically is uneconomic at use of raw materials and energy suppliers, and where there is the utilization of worn out equipment. Agricultural production has low efficiency and irrational use of agrochemicals. On the other hand, technological changes are comparatively expensive. The aggravation of environmental problems, accumulation of wastes, low efficiency of utilized technologies, and low quality of produced goods is the obstacles to restructuring of industrial production and its privatization. Thus, the restructuring of industrial production is a major issue in general development of national economy and also in implementation of environmental policy. Environmental priorities in the complicated situation of production occupy a comparatively low place. However, promotion of cleaner technologies can lead to the solution of both these problems. The role of promotion of cleaner technology and the tools to achieve these goals, the reduction of pollutant loads, and the achievement of better standards of living are still important issues in a society of transition.

2.5. Changes in human environment of Latvia

Latvia faces a tendency of population decrease since 1992. It is determined by two main factors: negative birth rate increase (death cases more than birth cases) and negative migration balance (immigration less than emigration) (Fig. 2.13.). At the beginning of 2004, there were 2319200 inhabitants, that is, 12300 inhabitants less than was in 2003 or 339000 less in comparison with 1991 (Central Statistical Bureau…2004).

As to the gender, there is the following structure: men 46.3% and women 53.7% out of total population. As to the national composition, there are 54.8% Latvians (there is an increasing trend: 1989 - 52.0%, 1994 - 54.2%), 32.8% Russians (there is a decreasing trend: 1989 - 34.0%, 1994 - 33.1%), other nationalities - 12.4%.

The negative trend in migration balance observed at the beginning of 1990s could be explained by emigration of Russian military senior officers and their family members, then, it is revealed also in the national structure. Migration balance was the following: 1993 - 27884 thous., 1994 - 18810 thous (Fig. 2.14).

As to the demographical situation in Latvia, it is important to stress that since Latvia regained its independence, the situation has been unfavorable. The transition from one political and socio-economical system to market economy has caused the decrease of standard of living. That also affected the demograpical processes concerning Latvians. However, apart from economical difficulties, other nationalities faced with the problem of being in such a status where they did not have any guarantees in Latvia. This worries them much more than temporary economical difficulties, which influence all inhabitants of Latvia.

Due to the major financial difficulties people spend most of their income on food, rent, services, thus, they consider also very carefully whether to get married or not, or whether to have larger families or not. At present people quite often postpone their marriage or the birth of a child due to bad financial family budget. These are the things, which could be planned. However, there are other demographical processes, which could not be planned (death or divorce, migration), which could not be postponed to the later time, so irrespectively of required expenses, it takes place.

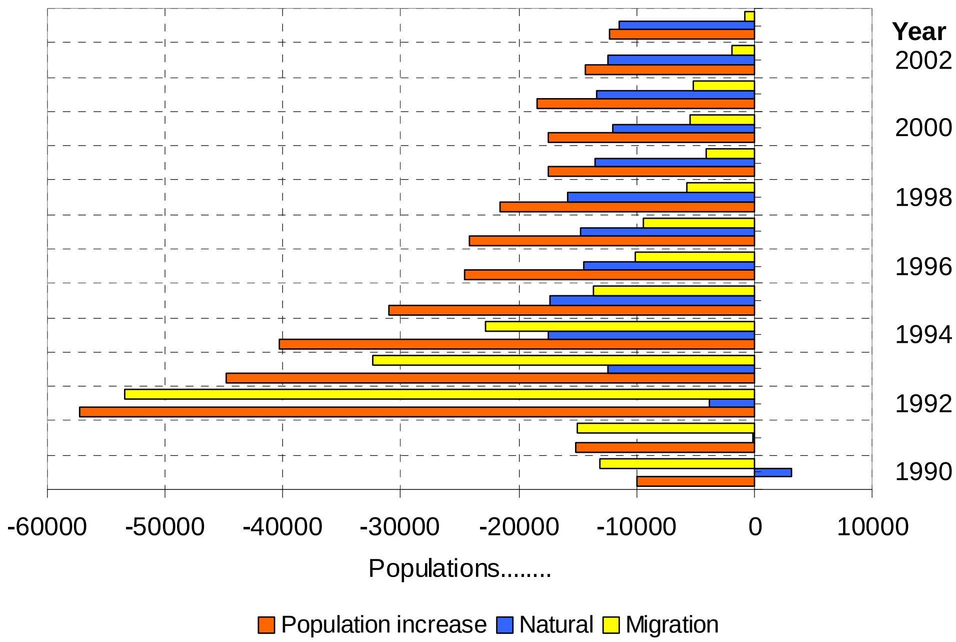


Figure 2.14. Population changes by year (Central Statistical Bureau…2004).

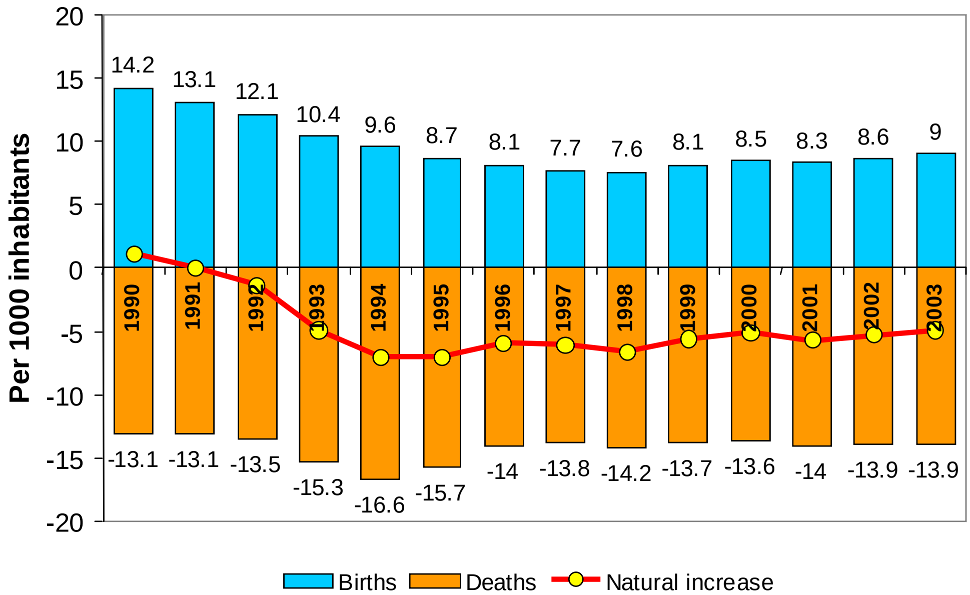


Figure 2.15. Characterization of the demographic situation in Latvia (Central Statistical Bureau…, 2004).

The associated changes in society, of course, have an impact on human health. In recent years, there are increased cases of infant mortality, mortality, deaths from cancers, tuberculosis and some other diseases, pinpointing social factors as the main contributors to poor public health.

For the first time after the Second World War, mortality exceeds nattily and a negative natural increase has been observed in Latvia. The mortality rate increased from 13.5 per 1000 in 1992 to 16.6 in 1994 (Fig.2.15.).

Correspondingly, perinatal mortality and natal mortality have increased. Natural population increase in Latvia is negative since 1990. There has been observed a decreasing trend in birth rate till 1997, now it is stabilised at a level about 8 births per 1000 inhabitants. The death rate is also stabilised since the middle of 1990s at a level around 14 deaths per 1000 inhabitants.

Life expectancy during the last few years has increased and in 2003 it was 65.9 years for males and 76.9 years for females (Fig. 2.16.), which still is among the lowest in Europe.

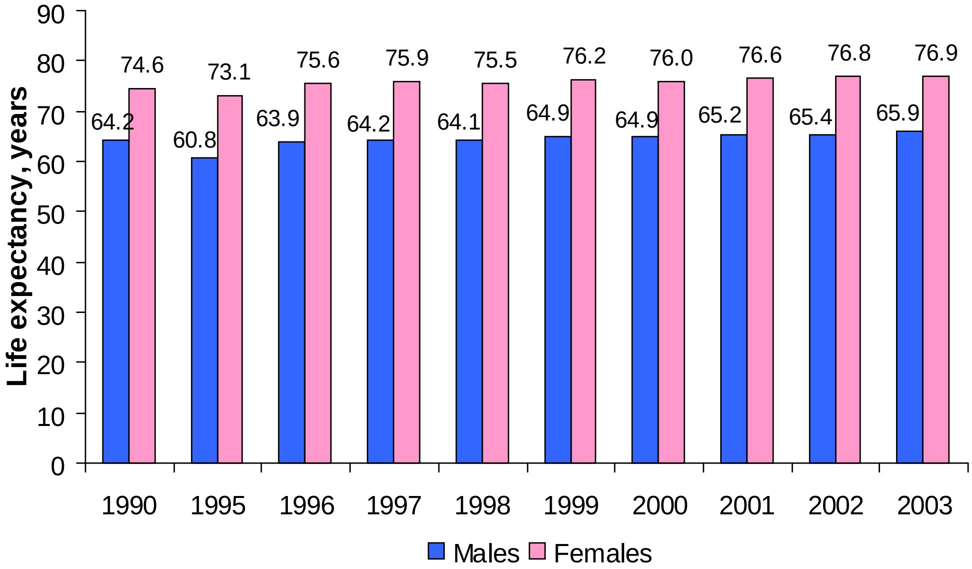


Figure 2.16. Life expectancy in Latvia (Central Statistical Bureau…, 2004).

Demographical situation in Latvia seems to be one of the most complicated ones among all other post-socialist countries. There is no other country, which has jacked such a huge influx of people than it was in Latvia.

Environmental quality in Latvia is to great extent determined by the significant concentration of inhabitants in cities, at first in seven biggest cities, where more than a half of total population is concentrated. On one hand it causes quite insignificant impacts on the environment in the countryside, but on the other hand most of production is concentrated in cities and also aggravation of environmental problems are associated with processes in urban environment. Spatial distribution of cities is closely associated with historical patterns of development of Latvia and all largest cities are directly located either at rivers or at the sea.

During the last decades the number of inhabitants in cities is slightly reducing, mostly due to changes in inhabitant migration patterns, but also considering increased number of population in the countryside and development of private owned farming. At the beginning of 2004, there was 67.8% of urban population, and 32.2% - rural population (Fig. 2.17.).

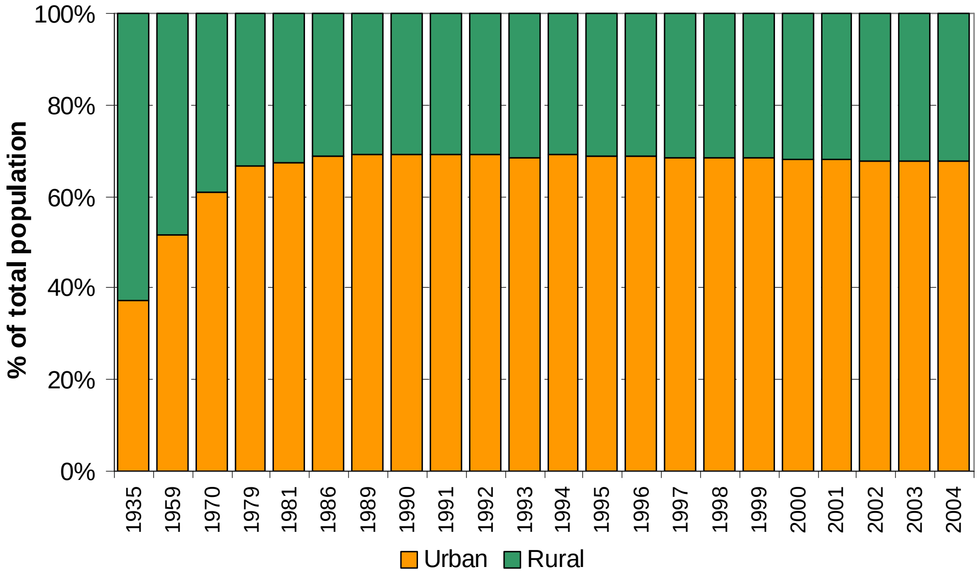


Figure 2.17. Changes of urban and rural population (Central Statistical Bureau…2004).

3 Environmental protection system of Latvia and its development

In Latvia the transition period has begun from a centrally planned to a market economy apart from the post Soviet Union and has been orientated to the utilization of local raw materials and natural resources. This process is associated with the development of democratical fundamental changes in the political system and in all sectors of society, including also environmental issues. Latvia's entry into Western Europe has created a new state environmental policy.

As the first step a united environmental institution at state governmental level has formed. In 1990 on the basis of the Committee of State Protection of Nature (CSPN) the Supreme Council formed *the Committee of Environmental Protection (CEP)* which continued the development of environmental protection system and its politics in Latvia after regaining its independence. In the summer of 1993 CEP and the Ministry of Architecture and Building joined as being the part of the Cabinet of Ministries and formed *the Ministry of Environmental Protection and Regional Development (MEPRD).* This ministry has carried out territorial planning as an environmental policy tool, enhanced development to reach sustainable development. This created a basis for environmental protection, its political development and its integration into all branches of economy. This is why MEPRD was responsible for the formulation and implementation of the policy of environmental protection, preservation of the natural environment, rational use of natural resources and building strategy. MEPRD consisted of six departments and eight subordinated institutions:

- State Environment Inspection, which implemented state control of environmental protection and the use of natural resources,
- Nine Regional Committees of Environmental Protection (now Regional Environmental Boards) which carried out functions of MEPRD at regional level,
- Environmental, Meteorology and Geology Agency,
- State Environmental Impact Assessment Bureau,
- Teiči Reservation,
- Slītere Reservation,
- North Vidzeme Biosphere Reserve.

In 2003 MEPRD was reorganised and the Ministry of Environment (MoE) was founded. The main functions of Ministry are:

- formulation and implementation of environmental policy along with different governmental authorities;
- carrying out State environmental impact assessment and establishing environmental protection requirements;
- supervision of environmental protection and natural resource use in the territory of Latvia.

Under the overall guidance of the MoE, nine Regional Environmental Boards (REB) are responsible for exposing environmental regulations, issuing permits for projects and providing public information services to twenty six regional administrative governments. Principal functions of Regional Environmental Boards are determination of pollution charges, pollution monitoring, inspection for compliance with requirements, imposition of penalties for non-compliance negotiation of steps toward compliance.

Responsibility for development, zoning and management of the coastal area and wetlands is delegated to local governments; they issue permits and licenses with co-approval of other agencies depending on the nature of the proposed activity.

Linked to the MoE is Environmental State Bureau under which are units such as Maritime Inspection, Forest Inspection, Fishery Inspection, Chemical Inspection and others.

While the MoE has a policy and coordination role, operational level responsibilities for municipal water and wastewater services have been passed to local governments as part of the process of decentralization. Under the Law on Local Government, the municipality is empowered to issue statutes, which grant municipal enterprises the rights, duties, and obligations necessary to enable them to carry out their functions. Such statutes generally follow a single pro-forma, which is applied across the country, but which varies according to individual circumstances.

Environmental monitoring at the same time is implemented at the Latvian Environmental, Geological and Hydrometeorological Agency, having control laboratories, regional laboratories and a net of water, air, and soil sampling stations. This Agency is responsible for the collection, analysis and dissemination of meteorological, hydrological data concerning pollution, as well as, publishing of annual reports on coastal and freshwater quality.

The second very important step was to adopt a strategic document at national level for the first time in the entire history of environmental protection in Latvia. So, in 1995 the Cabinet of Ministers adopted *the National Environmental Policy Plan for Latvia (NEPP)* and it was revised in 2004. It was developed and elaborated under the guidance of the Environmental Protection Department at the MoE and in co-operation with more than 80 institutions and organizations. The NEPP formulates basic environmental policy goals for the coming 20-30 years, listing principles upon which the policy should be based, and instruments for its implementation. The NEPP also discusses and analyses priority problems. It should be noted that priorities have been set at different levels according to the effects of time and location. So, it is necessary:

- to develop an environmental protection system in Latvia;
- to improve cooperation with foreign partners;
- to inform producers and the public in advance about increasing environmental protection requirements and to allow public participation in solving environmental problems;
- create a basis for future environmental protection policy development.

The key term in the discussion of the environmental policy is sustainable development. Sustainable development is a vague concept that merges economic development and environmental protection, rather than viewing ecology, the environment and economy as conflicting ones, sustainable development views ecology and economy as coexistent.

The principles of environmental policy to a great extent are summarized in the NEPP. The NEPP sets out environmental protection policy goals for the coming decades, the principles adhered to while developing strategies, and lists the resources and mechanisms that may be used for the implementation of policies. During the course of policy development, priority environmental problems were analyzed and measures for their resolution were suggested. The main goals of NEPP are being declared in the following way:

- significant improvement of environmental quality and ecosystem stability;
- protection of existing biodiversity and landscape characteristics of Latvia;
- sustainable use of natural resources;
- integration of environmental policy in all branches of life.

The general principles for the elaboration of environmental policy include:

- maintenance of balance between the environment and the national economy;

- principles of individual responsibility, publicity, consideration of historical experience at development of environmental policy principles;
- pollution prevention at the source and the “polluter pays“ principle;
- decentralization and precautionary principle, and integrated approach to problem solving;
- the principle of the use of best available technologies and application of the best practicable measures.

Information system, the development of environmental protection institutions and public awareness is being regarded as the most important prerequisites for the development and implementation of environmental policy.

In the future, as Latvia develops socially and economically, the overall environmental situation will also change its priorities. It will be necessary to modify, to improve and to supplement the NEPP. The NEPP document will also be used without delay to development of the next document in the series - *the Environmental Action Plan.*

In order to preserve the environment, the government has begun to apply traditionally used *economical, technological and regulatory incentives.*

Economical measures. The goal of economic instruments is to reduce pollution by ensuring that polluters and consumers voluntarily make the best choices for the environment. In fact, they establish financial feedback links between polluters and the public. In many cases they are more efficient, since they have an immediate effect on a polluter’s budget.

The legal base for the system of charges is the Law “On Nature Resources Tax“. The Law “On Nature Resources Tax“ charges enterprises for amounts of substances emitted into the environment (air and wastewaters) and for wastes which are transported to waste treatment sites. The amount of substances being taxed is determined yearly. The control of this process is carried out by the State Environmental Inspection. If the inspector finds that the actual emissions or wastes are emitted in quantities that exceed the licensed amount or their composition do not correspond to the expected (licensed), then the enterprise is charged in amounts exceeding the limit 5 times. However the final sum, even in the case of exceeding limits, is comparatively small and procurement of the fine from state enterprises is fairly complicated. A much better system of charges has been introduced concerning accidents (spills). The charges for accidental spills (oil, chemicals) in natural waters or in soil are high but the mechanism of charging of fines does not function. The problem has to identify these spills. It is possible to find spills of odorous substances, oil and oil products and other identifiable substances, but others present some difficulties.

The first Law on Natural Resources Tax was introduced in Latvia in 1990. The development of the legislation system and economy tax has not promoted pollution abatement and resource conservation because the rates have devalued. The tax revenues are also inadequate to compensate the damage to the environment. It is cheaper for a polluter to pay a fine for excess pollution than to invest funds to avoid it. A new Law on the Natural Resources Tax was adopted at the end of 1995 and has introduced on the January 1, 1996. According to the new law, taxes will be paid for abstraction of natural resources, emission of pollutants in the environment, environmental or resource degradation, and the sale or import of goods and products harmful to the environment. In this law new approaches will be implemented with the aim to more directly influence the producer. In the proposed law, the fine amounts will be more increased and the law includes a concept on tax of some hazardous substances (also if the substances have been imported) such as mercury, mercury containing products or mercury compounds, lead, lead containing products etc. Production or technologies which result is hazardous wastes will be charged with a fine.

An important tool in the implementation of the environmental protection policy is *a system of regulations.* “Environmental Standards in Latvia“, the regulatory legislation for water and air pollution is based on the EU environmental quality standards. The existing legal system sets out the system of charges for the use of natural resources and for taxes on the discharge of pollutants. The existing regulatory and constraining legislation is regarded as an economic incentive to reduce the pollutant load.

Normal *tax revenues* are divided, with 25 percent going to the state budget and 75 percent being paid into the local government budget. Tax revenues for discharges in excess of the prescribed limits are paid into the Environmental Protection Fund which collects fines that are used by the national and local governments to fund a wide range of activities. The monitoring of pollution and natural resource use for assessing fees and fines is hampered by the lack of equipment and personnel in the Regional Environmental Boards. During economic recession (when many enterprises are not able to pay taxes, for example social taxes), it is useless to require high taxes from state owned inefficient enterprises. All these questions are related to tax policy in Latvia. Also, the system of licensing/permits is a tool in prevention of environmental pollution.

There are two types of pollutant emission (into air, water and soil) *permission permits* (temporary and regular permits). Permits are issued by the Regional Environmental Boards (REB), but the control of emissions is implemented by the Environmental Protection Inspectorate. For example, in case of water permits they states the quantity of water that may be used and how much pollution can be emitted. They also set out:

- the water procurement and utilization requirements;
- wastewater drainage specifications;
- the payment for water use;
- the procedure for the issue of the permit; the rights and duties of the water user.

Existing standard system is related to *standards of air, soil quality, product contamination levels* and other variables.

Technological measures are associated with new modern technological improvement to reduce pollution and to effectively utilize resources. However, at the present situation, essential changes in this field are not likely to be achieved. Efficient use of foreign investments is also going to become possible after restoration of private tenure and implementation of economical reforms.

Now the environmental protection strategy is mostly oriented towards the regulation of the pollution source and improvement of technology. Thus, the existing environmental policy is more linked to the economic, legal and structural changes in society, but at the same time is more dependent on them. In this respect economic preconditions have become a base for environmental protection. Economic viability of the environmental protection measures is being assessed. The main environmental strategies include:

- Initiation of the decentralization process. However, at present, decentralization and deregulation are often used phrases, but regulation and centralization prevails. This is determined by the fact that the development of local and self-governments is still in a very early stage;
- Increase of user-charges, to cover expenses for exploitation of waste water treatment devices, waste handling e.g. -marketization;
- Privatization in the environmental protection system: support for development of private owned environmental business (audit, consulting enterprises). Privatization of environmental protection plants;
- Traditional protection of endangered species, habits, vulnerable ecosystems and areas;
- Internationalization of local and regional environmental problems.

However, the economical problems with which Latvia is faced now, cause very severe limitations on these desires. During the general recession in recent years, the state revenue, and, hence, budget expenditures for environmental protection, have been reduced. A more ideal solution, development of new technologies with environmentally more friendly methods of production, has been implemented in very few cases.

Regulatory measures. Since 1991 several important environmental laws were passed. The main laws on environmental protection were adopted:

- The Law "On Environment Protection" (1991),
- The Law "On Specially Protected Nature Areas" (1993),
- The Law "On Natural Resources Tax" (1995)
- The Law "On Subsoil" (1996)
- The Law "On Protected Belts" (1997)
- The Law "On Environmental Impact Assessment" (1998)
- The Law "On Chemical Substances and Chemical Products" (1998)
- The Law "On Radiation Safety and Nuclear Safety" (2000)
- The Law "On Protection of Species and Habitats" (2000)
- The Law "On Waste Management" (2001)
- The Law "On Pollution" (2001)
- The Law "On Packaging" (2002)
- The Law "On Water Management" (2002)

Laws defining the procedure of State Ecological Expertise, and governmental control over standards of environment quality and natural resources were implemented.

Latvian environmental legislation is influenced also by the signing of international agreements. Latvia has become party to several conventions and several others are signed and prepared for ratification. Convention requirements have also been included in Latvian laws.

The existing legislation in the area of environmental protection as well as the whole legislation in force in the Republic of Latvia comes primarily from the following sources:

1 Legislation adopted during Latvia's years of independence before World War II;
2 Legislation adopted during Latvia's incorporation into the USSR;
3 Legislation adopted since regaining of independence.

Closely related to the system of environmental regulations is environmental impact assessment (EIA) process. Following activities and plans are subject to the state EIA:

- pre-planning documentation for all types of economical or territorial development;
- planning and research materials;
- new technological development, materials;
- the environmental status of facilities, places and regions.

The main authority implementing the EIA is the Ministry of Environment and nine Regional Environmental Boards (REB). The process of EIA includes consultations of the developer with the REB to determine if an EIA is necessary and what environmental permits are required. The EIA focuses on compliance with existing legislative requirements both at national and international levels. The REB specifies the scope and format of the Environmental Impact Statement and provides the relevant environmental permit application forms. At the same time local public participation in the project evaluation can take place. Applications for environmental permits (emissions to air, water use and discharge) and for hazardous waste production, transport and disposal should be submitted to the local or central authority and to the corresponding municipality simultaneously with the Environmental Impact Statement.

A great role is played in the transition process by the communities of western countries and the increased internationalization of identified problems. Of these, environmental problems have a high priority. Environmental problems are often international, such as transboundary transport of airborne substances and pollution of the Baltic Sea.

Now the internationalization of environmental questions plays a crucial role in the strengthening of democratic traditions and newly developed democratic institutions in the formed Republics. The development of international cooperation in the field of environmental protection is recognized as important, both in the West and in the East European countries. Latvia is no exception. Inter-governmental environmental cooperation is especially orientated to the protection of the Baltic Sea. At the same time, intergovernmental agreements serve as a basis for broader development of projects, the aim of which are to solve environmental problems. The environmental problems that are in focus presently include hazardous and municipal waste treatment, development of environmentally friendly technologies, protection of the Baltic Sea basin and others. Different cooperation activities cover nearly all of the most important environmental issues. The fate and impact of cooperation on solving of environmental problems and development of the local learning process can be discussed in different terms, but one of the most important criteria is the efficiency of the implementation of the obtained results and impact of environmental cooperation projects, activities and aid on the transition process. Another aspect is the involvement in international cooperation system which could protect Latvia from pollution coming from neighboring countries.

4 Environmental and investment policy in area of city impacts on water quality

Economic activities in Latvia influence the inflow of nutrients in Latvia's lakes and rivers, as well as in Riga Gulf and the Baltic Sea, considerably speeding up natural eutrophication. Three largest cities of Latvia – Rīga, Daugavpils and Liepāja are identified as *hot spots* within the framework of HELCOM Baltic Sea extended environmental action programme. Canalisation systems and wastewater treatment plants do not meet modern requirements also in many small and medium size towns in Latvia. In the result environment is being polluted, inhabitants do not receive qualitative wastewater collection services.

National Environmental Policy Plan set the following environmental protection priorities - prevention of water eutrophication and degradation of water eco-systems, promotion of rational use of water resources and provision of drinking water quality. Improvement of water management, in its turn, is set as a priority in the Environmental sector of the National Development Plan, Public Investment Programme and National *ISPA* Strategy.

The biggest investments within the Public Investment Programme have been made for water management projects (Fig. 4.1.). Priority sector in environmental protection for international co-operation also is water management projects (Report on environmental

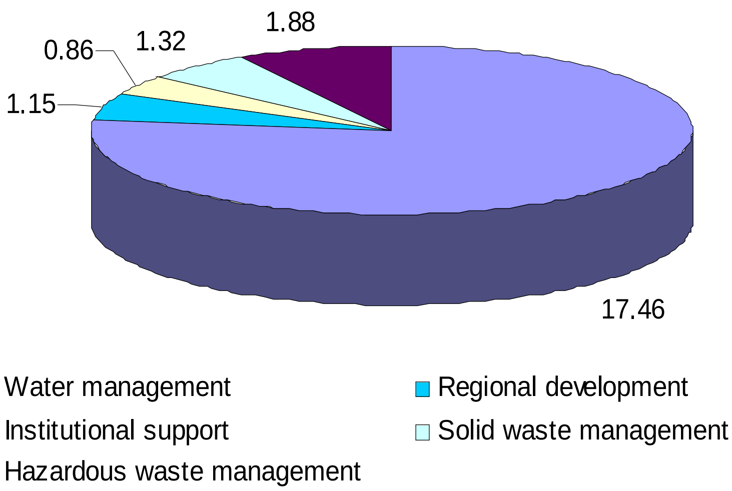


Figure 4.1. Investments for infrastructure projects, year 2001, million LVL (Report on environmental investments 2001).

Low drinking water quality is a priority in the development of water management sector in cities. One of essential problems in water protection is eutrophication, due to insufficiently treated wastewater from urban areas and non-point pollution from agricultural areas. Although total amount of pollution in the waters reaching the water bodies decreases, due to reduction of industrial production, the Baltic Sea in economical zone of Latvia carries medium pollution. Rīga, Liepāja and Daugavpils are considered as "hot spots" of the Baltic Sea Joint Comprehensive Environmental Action Programme developed by HELCOM. To fulfill the commitments Latvia has undertaken signing the Helsinki Convention, water management development projects were initiated in large cities in the middle of 90ties and the National Programme "800+" was developed to solve water supply and wastewater treatment problems in small Latvian towns. The aim of water supply and wastewater treatment programme is:

- to improve the water quality in the Baltic Sea, the Gulf of Rīga and other water bodies by reducing the pollution load,
- to prevent threats to human health caused by, for example, low quality of drinking water,
- to improve the general level of service in water supply and waste water treatment,
- to provide the implementation of international agreements and the EU directions in improvement of environmental quality.

To reach these aims several water management projects in largest cities of Latvia has been realized.

Rīga Water and Environment Project was started in 1997 and was completed until 2001. The main activities of the project were:

- establishment of safe and qualitative water supply system in the city;
- waste water treatment according to the international requirements;
- reconstruction of the municipal enterprise "Rīga Water".

Daugavpils Water Supply and Sewerage Project was a part of the World Bank joint municipal project in Latvia. Implementation of the project has ensured the water supply to Daugavpils from ground-water sources and updating of the waste water treatment facilities and pumping station. Besides, the project has included also the restructuring of the "Daugavpils Water" Ltd, introduction of the computerised and automated accounting system, introduction of water-meters and partly replacement of the laboratory equipment.

Liepāja Water Management Project is a sub-project of the Liepāja Environment Project and it resulted in:

- the reduction emissions of the partly treated and untreated sewage waters in the Baltic Sea;
- re-establishment and improvement of water supply in Liepāja, increasing the number of consumers joined to the centralised water supply lines, and re-establishment water supply systems, pumping station;
- improvement of the level of water management service in Liepāja, raising the efficiency of Water and Public Utilities Enterprise in Liepāja and establishing modern enterprise management systems.

The requirement for the overall Latvian water management development programme emerged already in 1995. After implementation of the pilot project in Bauska district in 1995, when analysis of inventory results of sewage water systems showed the critical situation in water management, the next step was the inventory of water management in all over Latvia. Till the end of 1995, there were investigated all sewage treatment systems with daily water flow more than 5 m^3, and all water supply systems in towns and villages with the population more than 2000. The inventory reflected that in 159 sewage treatment systems out of 1100 only mechanical sewage treatment was performed. In about 50% of cases treatment systems were in unsatisfactory condition (Fig. 4.2.).

With the support of the EU Phare programme there was elaborated investment strategy for water management development in small towns of Latvia, to determine the priorities for financial and technical assistance. This strategy was adopted by the Cabinet of Ministers in January 1997. Now all towns and rural territories, excluding the large cities of Rīga, Daugavpils and Liepāja, are considered as target group of the National Programme "800+". The problems of water supply and waste water treatment in small Latvian towns are being solved in the framework of the programme "800+".

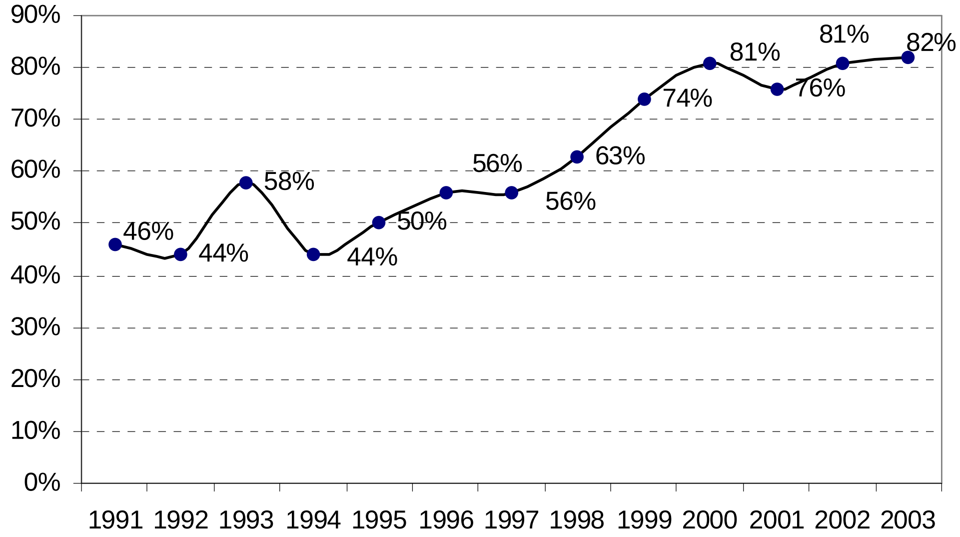


Figure 4.2 Percentage of purified wastewaters of their total amount in Latvia.

The water supply projects are related to providing of qualitative drinking water and improvement of safety of supplying systems, including:

- Improvement of water extraction places, including boring of new wells, also establishment of water supply accounting and control system;
- Preparation of the drinking water according to the EU standards. To provide the drinking water there are usually used ground-water resources the quality of which correspond to drinking water quality standards, except increased iron and water hardness. However, the clogging up of the water pipes is still observed, which is caused by the so-called secondary pollution of drinking water. It may cause also the bacteriological pollution decreasing the quality of drinking water. Besides, the clogging of pipes causes exploitation problems of pipes, why urgent is the question about construction of new facilities or the reconstruction of the existing ones for the preparation of the drinking water;
- Replacement and expanding of the water lines network.

The main objective of the public utilities and sewerage projects is to improve the quality of environment, including:

- Reconstruction of waste water treatment systems or construction of new systems. The main problems are related with insufficient refinement of the water (especially separation of nitrogen and phosphorus), inadequate capacity of the facilities, ineffective use of energy resources and applying of outdated constructions;
- Increasing of the quality and safety of waste-water collection systems, so that emission from waste water would not pollute groundwater resources.

It is planned that in larger towns (population over 50 000) standards in water management meeting the relevant requirements of the EU directives will be reached until 2010, but in other towns - till 2020.

To realise the improvement of water management infrastructure within the framework of the programme “800+“ there are possible four types of projects:

- feasibility study and capital investment projects,
- institutional development projects,
- the projects based on the river basin areas,
- demonstration projects.

Demonstration projects are envisaged for finding different solutions to the typical problems in this field all over Latvia. Initially these projects were planned for the municipalities with the population under 5000. But practically none of the demonstration projects have been realised because financial institutions have not shown interest in financing of small specific projects and development of the relevant monitoring system. Small projects predominantly are financed by the Environmental Protection Fund of Latvia, but they cannot be regarded as demonstration projects. Those are capital investments in several water management objects to prevent their further deterioration or to diminish their operational costs.

Partially as demonstration projects can be regarded the projects realised by the municipal partnership, where water management enterprises of several local/rural municipalities create a joint management unit and come to agreement on the implementation of the joint investment programme. It means that the serviced territory and a number of the serviced inhabitants are increased, thus providing better project capacity and viability. First of these projects will be implemented in the North-Kurzeme (local municipalities of Kolka, Tārgale, Ance and Dundaga). In case the projects turn out to be successful, similar projects might be started in other places of Latvia, because interest about possibility to take part in this programme has been expressed by many local municipalities.

The essence of the river basin projects is that they combine traditional feasibility study and capital investment projects with the development of the basin management plan. It means that priorities of investment programme are determined for the whole river basin, not only in several towns. To improve water quality in the water bodies in accordance with the certain set standards, the selection of the river basin projects should be oriented towards single river or lake basins. This type of projects could be developed for the river basins covering wide river deltas, small rivers with direct fall in Baltic Sea or the Gulf of Rīga and small rivers falling in inland lakes.

The aim of institutional development projects is to establish relevant water management structure to provide the implementation of the planned investment project and successful system management after the completion of the project.

Although every feasibility study carries out the analysis of a town water management, not always there is planned a management/operational system improvement project. Mostly these projects are realised in cases when one of the donor institutions is NEFCO or *Sida* and there is involved a partner town of Scandinavia. For example, business plans are elaborated in the framework of projects in Ainaži, Saulkrasti, Limbaži, Sigulda and Salacgrīva, training is foreseen for the representatives of municipalities on management and administration of an enterprise, accounting and control and on the work with the clients. Similar projects are realised in Cēsis, Madona, Aizkraukle and Gulbene, too.

General financing scheme of the projects is 30:30:30:10, where equal should be parts financed by the state budget, grants and loans and also 10% from local municipal budget. There is possible variation from this scheme for small municipalities, so that the grants component can be increased even up to 100%. Total amount of investments and of loans has been reviewed in each case and depends on the municipality solvency. The investments in the programme projects are made by the state budget (earmarked subsidies), municipalities (earmarked subsidies), LEPF (grant), LEIF (loan) resources as well as foreign resources, including bilateral co-operation programmes with Finland, Denmark, Sweden, the EU Phare National Programme and Cross-Border Co-operation Programme as grants and loans by NEFCO, NIB, EIB (Table 4.1.).

Investment policy is balanced, considering necessities in the field with the state budget capacity and foreign financial assistance to the state budget, including the EU funds (*ISPA, Phare).*

Table 4.1. Investments for the National Programme "800+", million LVL (1994-2001).

Year	State budget	LEPF	Local loans	Municipality	Private institutions	Bilateral co-operation	EU Phare	Internat. loans	Total
1994	0.110			0.009		0.055			**0.174**
1995	0.885			0.005	0.002	0.000	0.004		**0.896**
1996	0.500			0.079	0.047	1.938	0.600		**3.164**
1997	0.307			0.080	0.05	0.124	0.050	0.587	**1.198**
1998	2.572	0.846	0.303	0.472	0.11	1.201	2.320	0.100	**7.924**
1999- 2001	8.635	2.718	3.820	2.115	0.165	2.286	9.512	2.097	**31.348**
TOTAL	**13.009**	**3.564**	**4.123**	**2.76**	**0.374**	**5.604**	**12.486**	**2.784**	**44.704**

Latvia will have to ensure co-financing to environmental protection investment projects that will be financially supported by the EU funds for the introduction of the EU Directives and for ensuring performance of international commitments. Developing investment strategy the biggest contribution is supposed to come from the EU Structural Fund as a foreign assistance to the state budget in environmental protection. The rest of project costs shall be covered from the municipal or enterprise funds (Table 4.2).

Table 4.2. Investments for the National Programme "800+", million LVL (2003-2006).

	2003	2004	2005	2006
GDP, million. LVL	5657.4	6171.3	6723.7	7322.8
State budget investments in environmental protection and foreign assistance to state budget in environmental protection, million LVL	31.3	32.5	46.5	33.8
Total necessary investments in environmental and nature protection, million LVL	**46.2**	**47.7**	**64.5**	**55.7**

Water management development projects deal with both – drinking water preparation and water supply, and wastewater collection and treatment according to Programme "800+" that covers technical, institutional, financial, economic and project management factors.

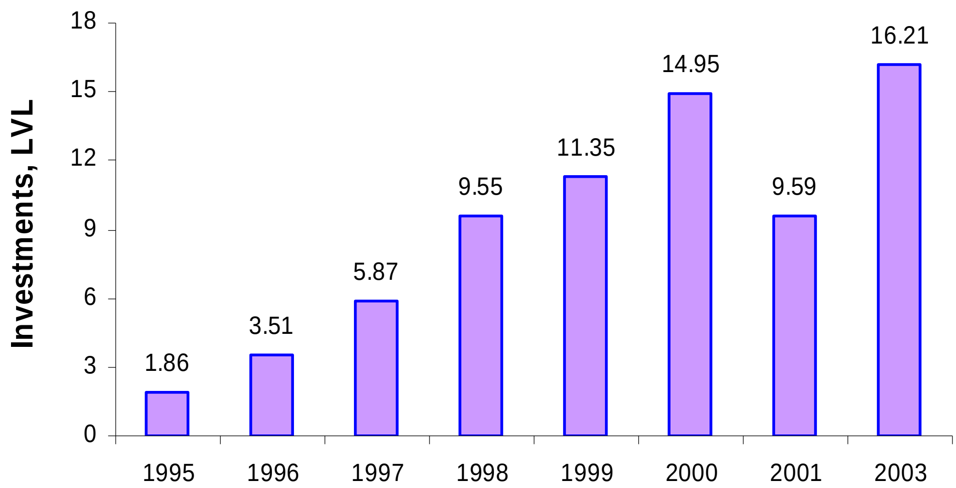


Figure 4.3. Changes of investments in area of environmental protection per capita.

Statistic data prove that 257 million m^3 were canalised in 2000 – approximately 190 million m^3 or 74% complied with the existing waste water outflow standards, 22% were partially treated but 10 million m^3 or 4% were canalised without treatment. Municipalities have to ensure wastewater collection and treatment in compliance with environmental protection norms (Table 4.3).

Table 4.3. Wastewater treatment parameters.

Size of a town (according to human equivalent)	Maximum permissible concentration in waste water according to the EU Directive 91/271/EC, mg l^{-1}				
	BOD_5	ChOC	SS_{total}	P_{total}	N_{total}
>100 000	25	125	35	1	10
10 000 - 100 000	25	125	35	2	15
2000 -10 000	25	125	35	-	-
<2000	For rivers with high self-purifying capacity, mechanical purification could be sufficient.				

Main components of water supply projects for water management investments are:

- Well field construction;
- Renovation, modernisation or construction anew of wastewater treatment plants;
- Water distribution network cleaning, renovation and extension, including disinfections and elimination of leakages that will prevent irrational usage of water and reduce drinking water bacteriological pollution possibility;
- Renovation, modernisation or construction anew of water pumping stations and reservoirs.

Main components of waste water collection and treatment for water management investment projects are:

- Renovation, improvement or construction of wastewater treatment plants;
- Cleaning, renovation and extension of sewerage networks, including leakage prevention that reduces pollution of ground waters and infiltration;
- Renovation, improvement and construction of wastewater pumping stations.

Evaluating the strategy *Water Supply and Wastewater Treatment in Small and Medium Size Towns* and the development water management plans in the big cities, taking into account state and municipal financial capacity, paying capacity of inhabitants and requirements of the EU directives, 88 towns of Latvia (human equivalents >2000 or number of inhabitants > 1000) are divided in three categories according to the terms for introduction of the EU directives:

- Agglomerations with HE bigger than 100 000 (Riga, Daugavpils, Liepāja – total number of inhabitants – 0,968 million) - directives are to be implemented by 2008;
- Agglomerations with HE from 10 000 to 100 000 (20 agglomerations - total number of inhabitants - 0,460 million) - directives are to be implemented by 2011;
- Agglomerations with HE from 2000 to 10 000 (65 agglomerations - total number of inhabitants - 0,250 million) – directive has to be implemented by 2015.

In compliance with requirements of the EU Directives, centralised water supply and canalisation services in these agglomerations are to be ensured within a period of 15 years – till 2015 (Fig. 4.4.).

In accordance with the adopted quality standards of services, approximately 95% of inhabitants in the mentioned towns shall be ensured with centralised water supply and wastewater collection.

Required investments for waste water treatment and collection ~350 million LVL, required investments for water supply ~ 310 million LVL.

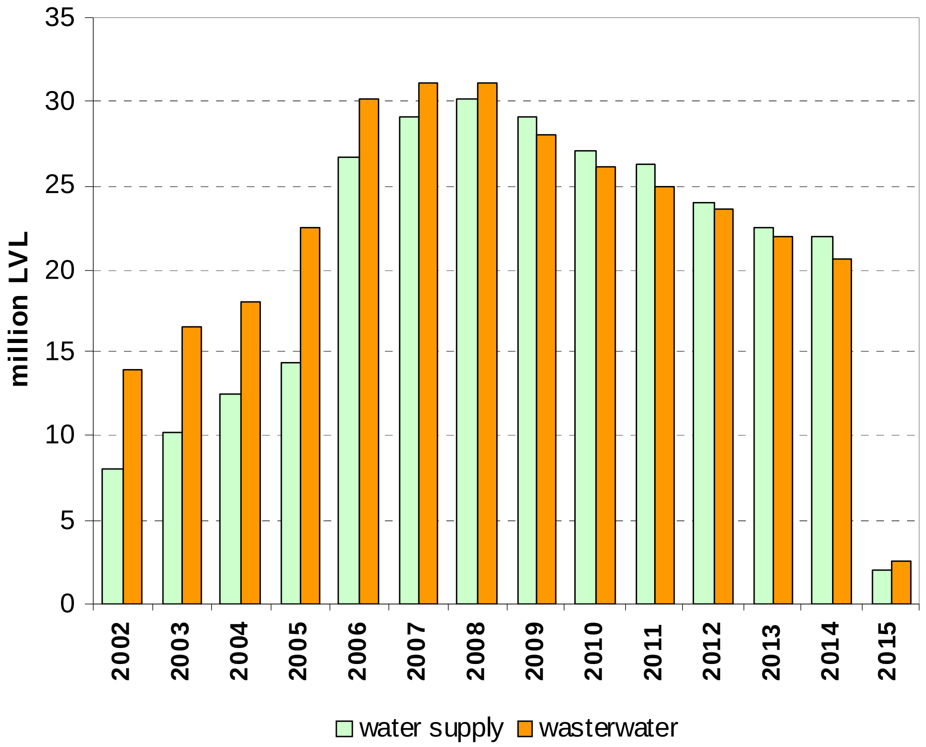


Figure 4.4. Finance plan for implementation of the EU Directive 98/83/EC and Directive 91/271/EC, million LVL

In order to ensure water resources management according to river catchment basins that is at the basis of Water Framework Directive, further on in evaluation of water management investment projects the following approach will be supported – towns will be grouped in one project according to river basin management area. Improving wastewater treatment in several towns simultaneously, pollution load in river catchment basins is considerably decreasing; the efficiency of investments increases ensuring water quality in the respective rivers. Besides, uniting water management projects the EU financial support can be allocated to those municipal projects that separately do not reach the amount of 5 million EUR.

5 Environmental quality in cities in Latvia

5.1. Air pollution

The method of industrial and agricultural production determines the existing levels of environmental pollution and is the source of the main environmental problems. Regarding the level of environmental pollution, Latvia is quite different from the other Baltic countries, as well as, Russia and Poland. It is much more determined by specific production and underdeveloped production of energy. Thus, air pollution levels in Latvia are much less than in Lithuania and Estonia. The total discharge of pollutants into the atmosphere from all air pollution sources in Latvia, per capita, is approximately one-half of that in Estonia and one third of that in Lithuania. The deposition of sulfur oxides and nitrogen compounds is dominated by long range transport, but local contributions are more important here than those in Nordic countries. The main sources of transboundary air pollution with nitrogen are: Germany - 20%; Poland - 12%; Great Britain - 13 %. At the same time the load from local sources is estimated less than 10%. Transport sources are among the most important pollution sources (Fig. 5.4.). The output from factories to the total pollution level has been assessed in the largest cities of Latvia - Rīga, Daugavpils, Liepāja, and Venstpils. 95% of emissions from stationary sources in Latvia in 1993 were created by sulfur dioxide (50.1%), nitrogen oxides (10%), carbon oxide (24%) and particulate matter (10.8%) (Fig. 5.3.).

However, the pollution load from industrial production within the last two years has decreased, mostly due to the reduction of production. On the other hand, the relative role of pollutant loads from transport is steadily increasing (per ~ 11% per year). This is evident when analyzing the trends in amounts of emissions of main pollutants: sulfur and nitrogen oxides. If until year 1992 it was common to observe the recessive trend in the amounts of emitted pollutants then for last two years their amount has increased (Figs. 5.1., 5.2.).

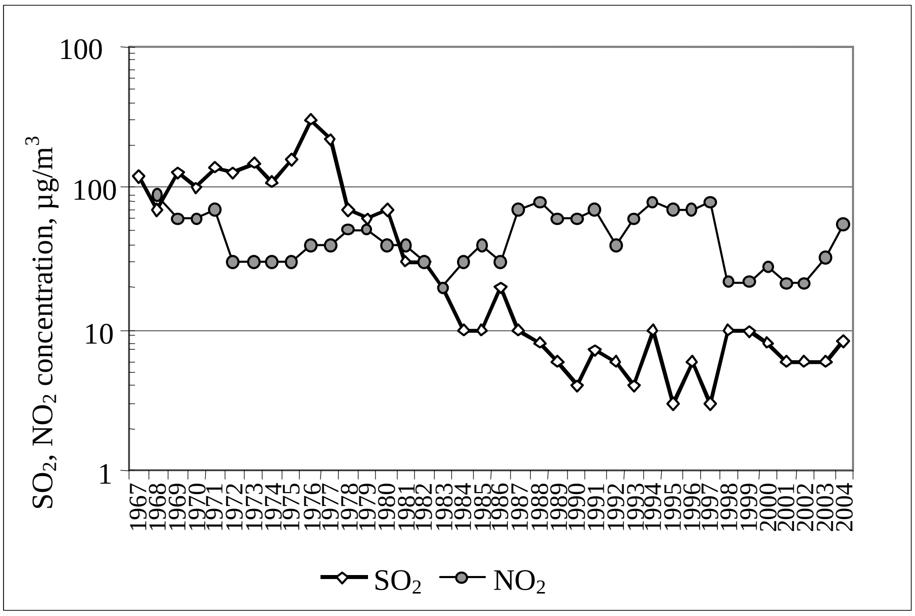


Figure 5.1. Changes of SO_2 and NO_2 concentration in the air of Rīga, 1967-2003

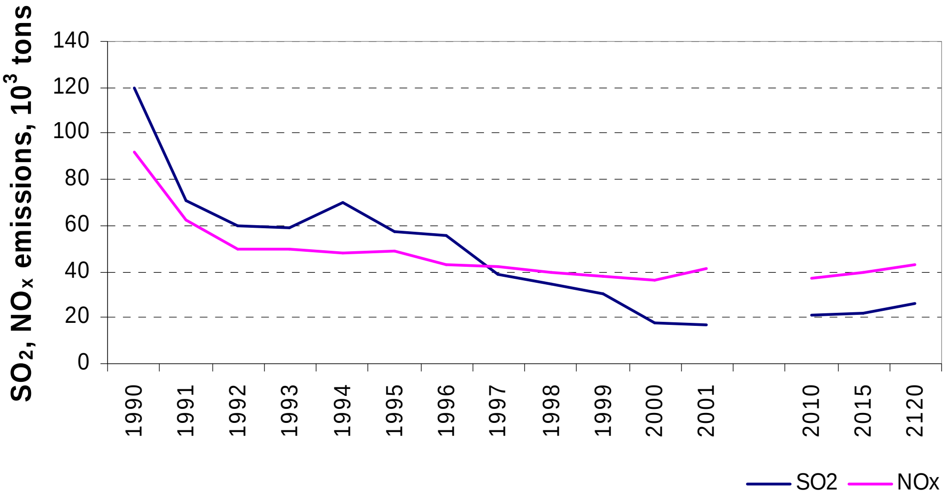


Figure 5.2. Changes of sulphur dioxide and nitrogen oxide emissions in Latvia (including forecasts)

Air pollution problem in Latvia is important in the largest cities and in the direct vicinity of large enterprises, as well as, indoors. In some biggest cities, but, especially, in Riga, the concentration of pollutants has increased (Table 5.1.). The atmospheric air of the towns is still badly polluted with formaldehyde, ammonia. This situation could change quite soon, if thermal electrical power stations are developed to cover demands, and if there begins the revival of industrial production. Also, other indices of air pollution levels (pollutants in mosses, pH of precipitation, chemical composition of dry deposition etc.) indicate commonly low levels of air pollution in monitoring stations far from industrial cities (Table 5.1.), for example, in Rucava.

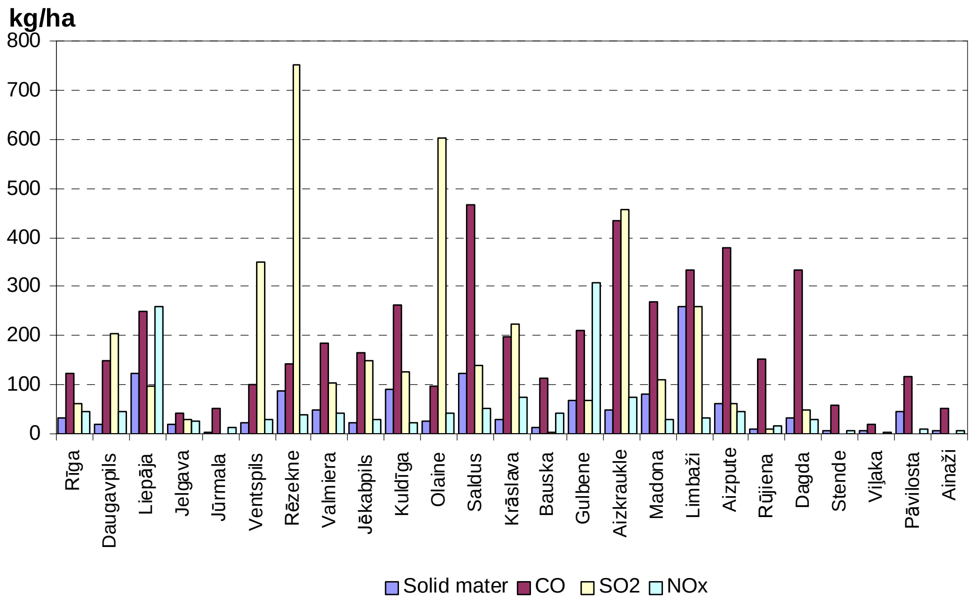


Figure 5.3. Loading of major airborne contaminants in cities of Latvia.

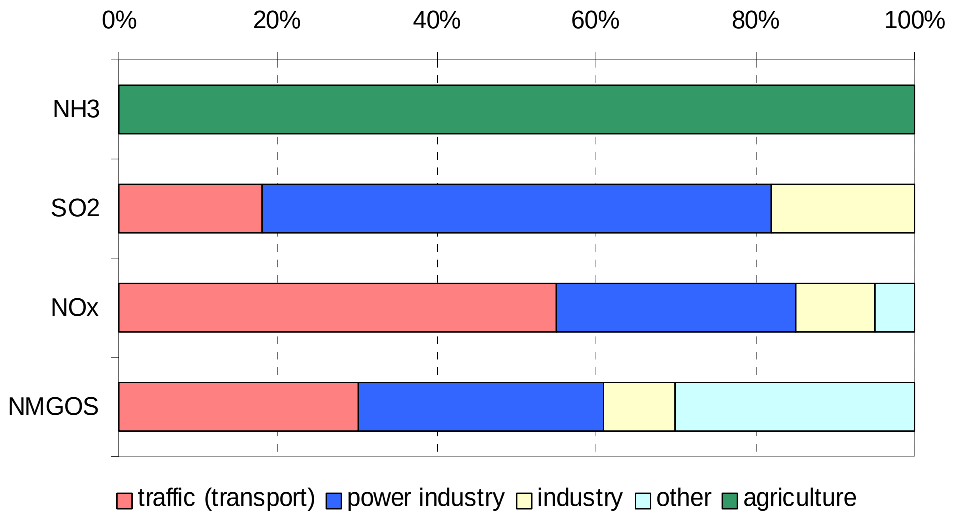


Figure 5.4. Air pollution emission character depending on the emission sources

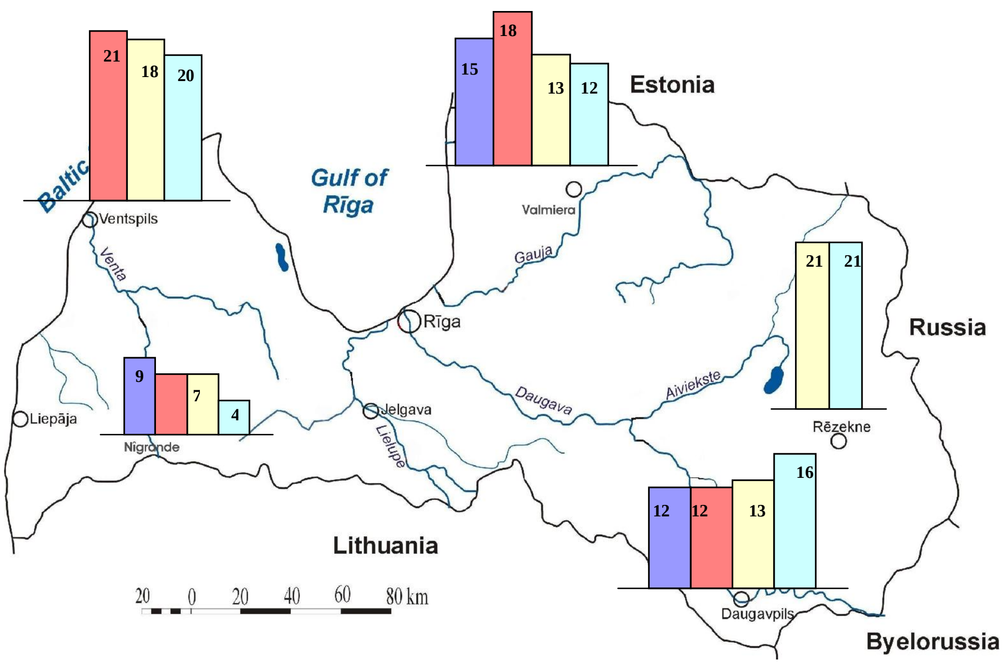


Figure 5.5. Mean yearly concentrations of nitrogen oxides in cities of Latvia, mg m^{-3}

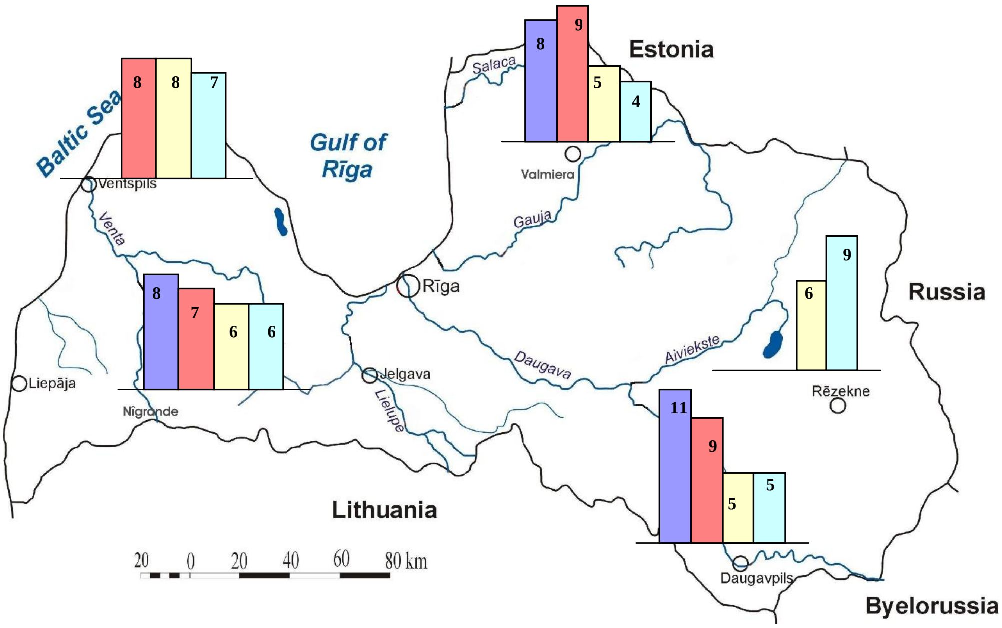


Figure 5.6. Mean yearly concentrations of sulphur dioxide in the cities of Latvia, mg m^{-3}

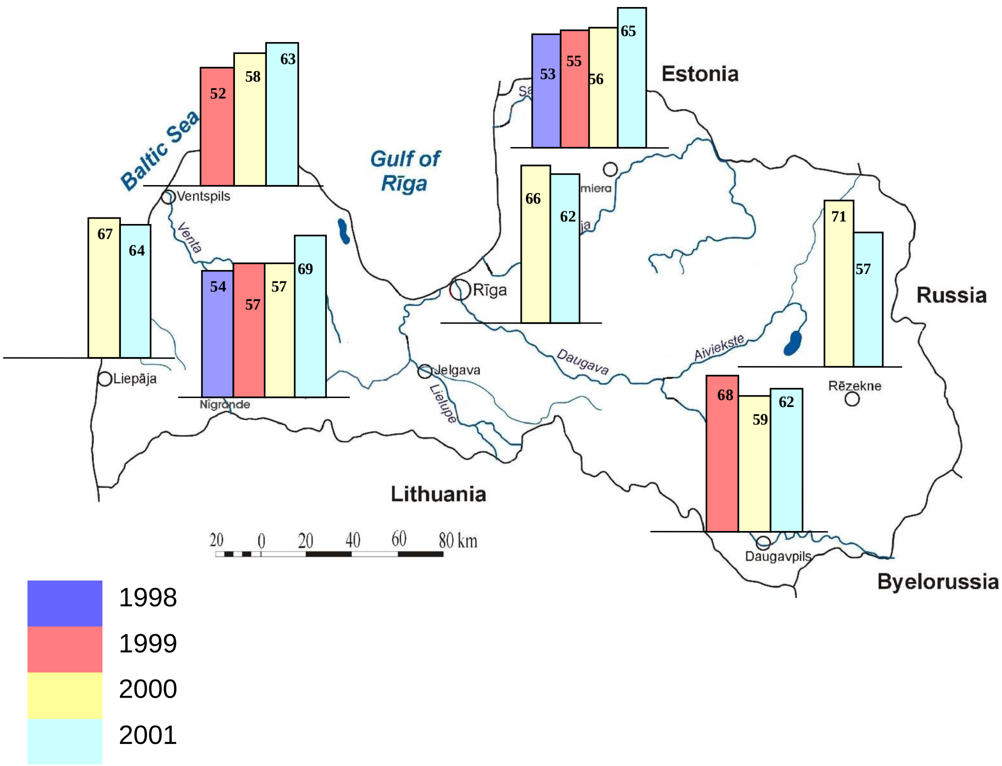


Figure 5.7. Mean yearly concentrations of ground-level ozone in cities of Latvia, mg m^{-3}

Table 5.1. Chemical composition of wet atmospheric precipitation in Latvia.

Station	SO_4 mg l^{-1}	Cl mg l^{-1}	NO_3 mg l^{-1}	NH_4 mg l^{-1}	Na mg l^{-1}	Ca mg l^{-1}	Cu μg l^{-1}	Pb μg l^{-1}
Dobele	15.37	10.77	0.93	0.93	5.58	11.20	13.84	1.62
Zilani	7.03	2.49	0.88	0.88	0.96	1.79	7.50	0.78
Liepāja	7.29	7.09	1.12	0.93	3.71	3.87	12.80	1.24
Zoseni	10.04	4.23	0.61	1.24	2.53	2.98	-	-
Rīga	16.25	4.28	1.15	0.97	2.13	3.32	-	-
Kemeri	6.29	5.23	0.84	0.99	1.24	1.44	21.68	2.03
Jūrmala	12.34	4.02	1.07	0.88	1.69	1.55	-	-
Rucava	3.48	2.83	2.70	1.08	0.64	1.38	12.91	2.81

5.2. Water pollution

Some of the most crucial problems of environmental protection are associated with pollution of inner waters. In Latvia, both water supply and sewage water treatment can be regarded as unsatisfactory. The main part of surface waters is polluted or slightly polluted. Up to 90% of lakes in Latvia are eutrophic due to the discharge of nutrients from domestic or agricultural sources (Cimdins *et al.* 1987). Most common is the pollution with nutrients, however, in several places the presence of other pollutants also has been found in high concentrations (e.g. heavy metals, detergents, phenols, pesticides and other priority pollutants, (Kļaviņš 1993). The most polluted areas are river segments located below biggest cities (Rīga, Daugavpils, Ventspils), as well as, some lakes where there is a direct discharge of wastewater going on (Lake Liepājas, Ķīšezers and other).

In spite of efforts, in 1989, only 42% of the total amount of sewage was treated according to standards. Recently, discharges of waste waters have decreased. The main reasons for the low efficiency of treatment facilities are as follows: 1) the lack of necessary sewage systems for enterprises and towns; 2) the lack of treatment facilities for preliminary treatment of waste water in the majority of industrial enterprises; 3) the mixing of different kinds of sewage without taking into account their specific composition and interaction before their entry into treatment facilities. The implementation of water treatment facilities has also decreased.

The largest cities of Latvia, mostly Rīga, are responsible for the main volume of untreated sewage. The first stages of biological treatment facilities in Rīga, as well as, in some other cities, are under construction. Partial development of new facilities proceeds with the involvement of Western experts.

The discharge of untreated sewage waters determines the high pollution level of inland waters and the Rīga Gulf. It has been demonstrated that the phosphorous and nitrogen pollution in the Gulf of Rīga has increased over the last 20 years. The enrichment of water with nutrients causes eutrophication with associated changes in the structure of living organisms and water chemical composition. At present the waters of the Latvian economic zone in the Baltic Sea are moderately polluted with some regions of elevated local pollution. Zones of ecological risk are coastal regions and river estuaries in the vicinity of cities.

The degree of surface water pollution in Latvia has not changed significantly in recent years, but the pollution of sea water near the mouths of the Daugava and the Lielupe rivers has increased due to large amounts of untreated sewage being discharged in Rīga. The decay of blue-green algae in the Gulf of Rīga caused health warnings to bathers during summer months. During recent years, there has been a sharp deterioration in the environmental state of smaller and medium sized rivers, due to agricultural runoff and an increase in the eutrophication in lakes. This trend is valid unless there will be recession in industrial and agricultural production.

In general groundwater in Latvia is quite clean thus enabling its use for drinking water preparation. Still for water supply of the biggest cities (Rīga, Ventspils, Daugavpils) surface waters are also used. An average of 95% of the population in Latvian cities receive their drinking water from a centralized supply system. However, in rural areas the most common source of drinking water still are wells of which up to 20% (Klavins *et al.* 1995) of are polluted. At the same time in the biggest cities (Rīga, Daugavpils, Liepāja, Ventspils, Jelgava) also qualitative drinking water sources have become exhausted: as a result of intensive use of groundwater, depression funnels have been formed in Rīga, Liepāja, Ogre and other cities. In this case there could be the possibility of intrusion of saline waters from the sea or contaminated waters from areas of waste dumping. There still exist quite many local pollution sources contaminating groundwater. It has been estimated to be 1000 sites where there has been found a substantial contamination of groundwater.

Intensive agricultural production affects the level of agricultural pollution. The main sources of environmental pollution in agriculture are leakage from facilities for manure and silage, mineral fertilizers (the use of which in the transition period has decreased), oil and use of pesticides, as well as leaching and surface runoff from arable land. Agricultural lands in Latvia are threatened by wind erosion (230000 ha or 14.7% of total arable land) and water erosion (380000 ha or 24.3%). Also degradation of rural landscape is of importance.

The processes that occur in the environment often have a time-delayed dependence on the processes in society. The changes in forested areas are nearly impossible to identify, unless the intensity of forest use has much increased over the last few years due to their privatization. Fertilizer use has decreased since 1989 in Latvia, but nitrate, phosphate, organic matter contents in waters of rivers show no downward trend. However, when processes in the transition period have changed the environment or the feeding conditions for living organisms, it is possible to identify ecosystem impacts. Thus, the transition process in Latvia has a diverse impact on processes in society and nature.

Now, the situation in rural Latvia is changing very rapidly, and correspondingly, the number of pollution sources and the intensity might increase in the future. Recent land reform put a substantial pressure on conservation of wetlands, which play a great role for trapping pollutants and their presence is of principal importance for preserving the endangered habitats.

The present decrease in the production of agriculture has reduced the pressure on the environment, and the natural environment has become less polluted than before. The use of agrochemicals has substantially decreased over the last years because the biggest users - kolkhozes and sovkhozes have been destroyed. At present the exact usage of fertilizers is not available statistically but expert agronomists have estimated that the application of fertilizers is below the necessary agro-technological norms. The statistics show the decrease of pesticides usage over the few last years. The relative low animal density suggests that the manure pollution is caused not by high animal density but rather by poor manure storage. Latvian soil can be considered relatively clean and should therefore be regarded as part of the national wealth. This is why in general, farmers are not interested in changing their methods of production in favour of an environmental friendly one. Another environmental problem due to the privatization of farm and forestry land is an intensive utilization of forests. Selling timber at the wood market is an important source of income for farmers who by cutting down forests violate the interests of natural environment protection.

The present underestimation of environmental concerns among farmers may cause problems in long-range perspective. They become economically stronger and so the present attitudes towards environmental issues do not change. Not only administrative and legislative measures are required to promote environmentally friendly and efficient agriculture, but also a lot of patient work in creating environmental awareness to farmers.

The ideas and policy of sustainable agriculture in Latvia emerge in a situation where domestic agricultural production has dropped, agricultural pressure on environment has decreased, and local food markets are filled with imported products as a consequence of trade liberalization.

The emergence of sustainable agriculture in Latvia could be seen as:

- an acceptance of the environmental protection obligations at a state/ political level;
- a well-developed institutional framework of the agricultural and environmental policies at national, district, and local municipality levels, particularly, the well-developed agricultural advisory system;
- practical incentives towards the more sustainable methods in agriculture, undertaken by governmental and environmental organizations, agricultural advisors and farmers;
- development of sustainable farming methods among advisors and farmers.

5.3. Waste treatment problems in cities of Latvia

Among the most important environmental issues, waste and wastewater treatment problems could be considered. Rīga agglomeration alone generates about 266000 tons of household wastes yearly or 240 kg of wastes per person. At the same time the changes in the structure and the composition of wastes continue. On the other hand, Latvia lacks facilities and experience how to treat wastes. Unless principal efforts are put to improve the existing situation many aspects of the waste and wastewater treatment still are not solved.

Another principal problem is the amount of toxic wastes which are generated in different industrial enterprises as well as wastes accumulated from previous years. The recent amount of hazardous wastes produced in Latvia is 80 000 tons per year (in 1989, 1990 it reached 200000 tons per year) (Fig. 5.8.). Among substances, which have accumulated from previous years, residues of pesticides and other toxic substances are worth mentioning.

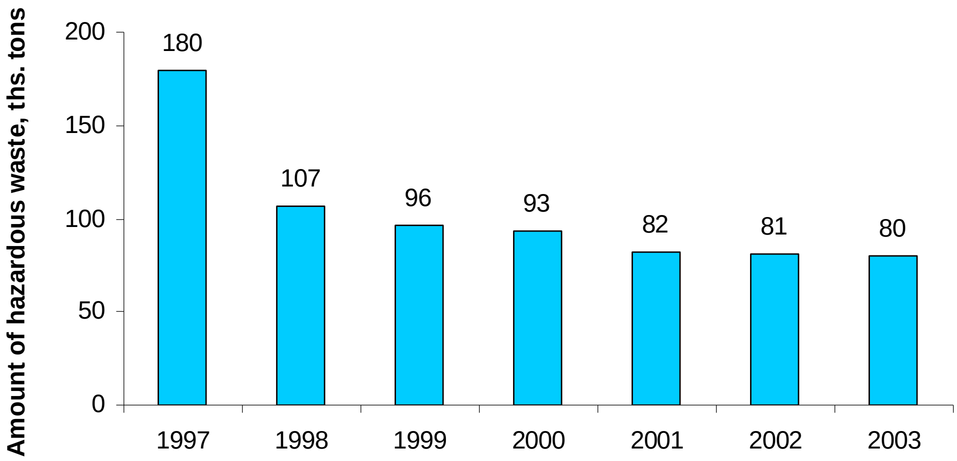


Figure 5.8. Changes in amount of hazardous wastes in Latvia.

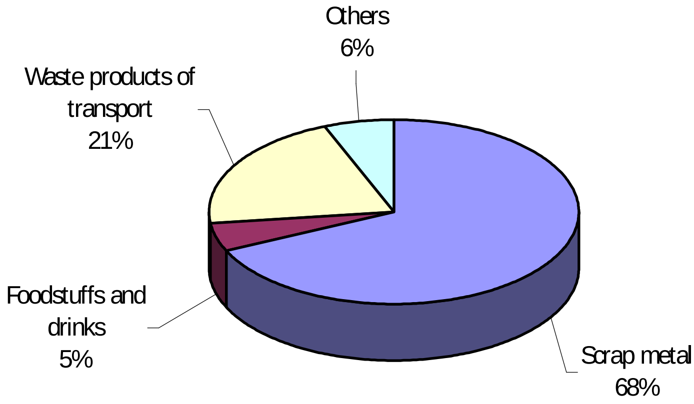


Figure 5.9. Production of toxic wastes by branches.

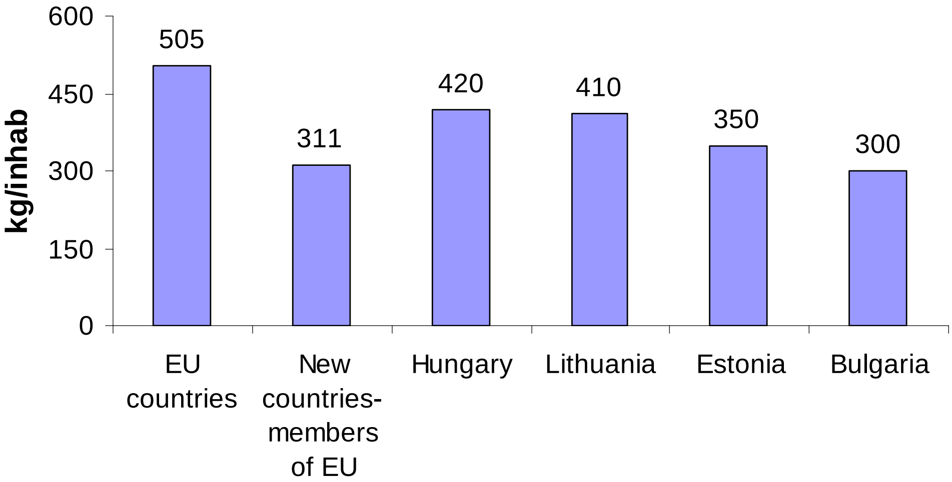


Figure 5.10. Amount of waste production in EU.

The nature conservation in Latvia. There are long traditions in nature conservation, which greatly are based on the first explorations of nature beginning from the 18th century in Latvia. 441,666 hectares or 6.8% of Latvia's territory are occupied by nature protection areas and objects. These areas can be divided into nature reserves, Gauja National Park, nature parks, protected landscapes, cultural heritage parks, natural monuments and others. The system of protected areas plays an important role in the preservation of biological diversity in Latvia. At the same time the transfer from centrally planned to market society has affected the nature conservation system as far as natural reserves and other protected objects which were established after the World War II are located on the territories which have become a private property. The existing legislative system states that protected areas will not be the subject of privatization. So, currently the protection of biodiversity of species of plants and animals should be ensured both by tested methods, such as the creation of protected territories, and by the introduction of new methods, for the protection of species being located the outside protected territories.

The diversity of impacts during the transition period can lead to 4 main consequences, depending on their manifestation in society:

- demographical consequences: fall of natality, increase of mortality, infection and social diseases, injuries, poisonings, homicides and suicides, reduction of life expectancy. New migration trends are also seem to be typical;

- economical consequences: recession in industrial and agricultural production, growth of unemployment, rapid fluctuations in economic activity, changes in consumption and most important, privatization with associated changes in the public attitude to income distribution, development of income inequality;
- social consequences: all changes related to the development of new structures in society and new social relations, changes in life style, development of a new system of values and priorities;
- environmental consequences: temporary reduction of pollutant load; changes in attitudes to natural values; internationalization of environmental problems.

All these processes have an impact on the transition process, and different aspects of changes in different stages of transition are expressed more intensively. On the other hand, the interdependence of all processes in society allows both the analysis of changes in society-nature relations and individual- society- nature relations.

As to the analysis of adverse impacts taking place during the transition period it must be stressed that their sources lie not only in the process of transition, but they can be regarded partly as a heritage of the former socialist regime. The fall of the socialist regime partly has increased the adverse impacts on nature. However, some aspects of the existing situation (demographical situation) can be regarded as extremely alarming ones and hence it requires an active intervention from the government. The protection of the human environment and human health can be regarded as priorities of environmental protection in the transition.

Loading to inland waters and the Baltic Sea

6

6.1. Loading to the Baltic Sea

Surface waters can be considered as a complex system containing numerous dissolved substances that determine the properties and practical use of the water. Investigations of the different sources of water ingredients are of the utmost importance in evaluation of water quality. The runoff of dissolved substances by riverine waters is an important factor in evaluating water quality, and even more important, in assessing the role of processes as sources of dissolved substances in the catchments of water bodies (Stumm and Morgan 1996). Rivers act as conveyers transporting dissolved substances from continents to seas. The integrated adverse processes in watersheds and increased geochemical mobility of dissolved substances can alter fluxes of dissolved substances. Pulses of high concentrations of dissolved matter can affect the living environment of aquatic biota, especially in receiving water bodies such as the Gulf of Rīga and the Baltic Sea. Human impacts in catchments of water bodies potentially affecting water composition include industrial production (wastewater and solid waste emissions) and agricultural activities (non-point sources of pollution). The different combinations of processes in a watershed determine the existing fluxes of substances in waters and their long-term and seasonal variability.

It is especially important to study changes in runoff when impacts are changing. In Latvia, this question is especially interesting considering the possible impacts on water quality from changes in human impact due to restructuring of agricultural and industrial production during recent years. Much evidence indicates substantial changes of anthropogenic loading and direct (discharge of wastewater, agricultural runoff) and indirect influences (changes in land-use and forest coverage). Protection of water quality is a priority in the newly developed environmental protection system and large investments has been recently made to reduce pollutant emissions to surface waters.

Regular observations of the concentrations of the main substances in water bodies have been made during a 20-year period, which allows a reasonably accurate calculation of the flow of these substances via river waters and their approximate budgets along the river flow. One of the main parameters determining runoff of dissolved substances is water discharge (Fig. 6.1.). The water discharge from rivers of Latvia differs between regions. The rivers in western Latvia, such as the Tebra and Venta Rivers, have two main discharge peaks: during the spring snow melt and in late autumn during the period of intensive rainfall. The rivers of eastern Latvia, such as the Gauja and the Dubna Rivers, are characterised by high snow-melt floods and comparatively lower autumn floods. About half of the annual river discharge in Latvian rivers occurs in spring. The main source of river water is precipitation, but underground sources may account for up to 40 % of the water inputs to some rivers (for example, in the Gauja and Daugava).

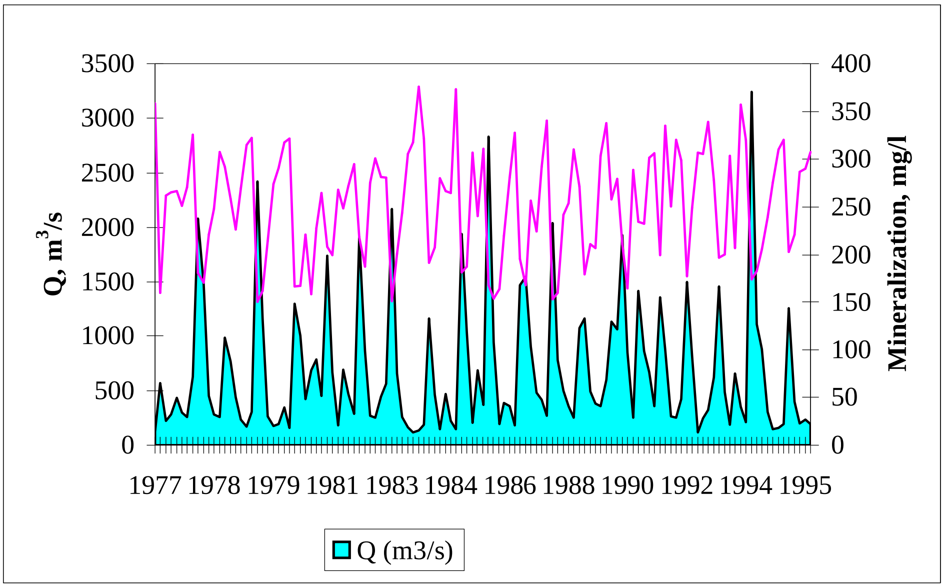


Figure 6.1. Long-term changes of Daugava River discharge and mineralization.

Long-term data on water flow, for example in the Daugava River, reflect processes that influence the hydrological cycle, such as solar activity, long-term atmospheric circulation patterns and changes in land use. The river hydrological regime determines water flow and hence also affects the water chemical composition. During the last twenty years (1977-1997), there has been a relative increase of runoff compared with the previous 20-year period: the water discharge of rivers in eastern Latvia has increased by ~ 10 %, and in the west (Venta, Tebra) by about 40 %. In the Daugava during the period of low water discharge (before 1977), there were four observations of minimal flow, and maximal flows exceeding the long-term means were rare. During 1977-1997, there were only two observations (in 1984 and 1996) of minimal flow in the Daugava, and the century maximum discharge (since 1897) was recorded in 1990.

The general aquatic chemistry of water bodies in Latvia is influenced by the soil composition, character of vegetation, precipitation, climate, land-use, and human impacts. The combinations of these factors differ for rivers from different regions. Hydrogen carbonate and calcium ions dominate among the water ingredients. Increased concentrations of sulphate and magnesium ions are observed only in several rivers of the Lielupe basin, and elevated chloride and sulphate ion concentrations sometimes occur in small rivers in coastal areas. Commonly, surface waters of Latvia are rich in organic matter, being highest in rivers of the Lielupe basin and in several small bog rivers. High concentrations of nutrients in rivers of the Lielupe basin can be explained by intensive agricultural production in the area. The intensive agricultural land-use in the Lielupe basin also leads to increased soil erosion, which in turn affects water chemistry.

The loads of dissolved substances from the territory of Latvia are summarised in Table 6.1. The largest loads enter waters of the Daugava River, from where most are discharged into the Gulf of Rīga (Fig. 6.2.). The loads of the main water ingredients entering directly the Baltic Sea are much less than those entering the Gulf of Rīga. Direct loads of inorganic substances (total mineralisation) to the Baltic Sea amount to only 18 % of the total load from the territory of Latvia, 10% of the total load of nutrients, and 10 % of the organic matter (as indicated by COD). Since nutrients and organic matter are subject to intensive transformation processes in the Gulf of Rīga, the actual load from the territory of Latvia to the Baltic Sea is relatively small, but more accurate estimates of water exchange between the Gulf of Rīga and the Baltic Sea are required. About half of the load of dissolved substances from the territory of Latvia enters via the Daugava River. Therefore, the nature of processes in this river generally determines the total loads from the territory of Latvia.

The specific loading or export value, defined as the amount of a substance in river runoff per watershed surface area, differs for specific groups of substances (Table 6.2.).

Export values of dissolved substances calculated using long-term mean concentrations and discharge data can be considered as reliable indicators of many processes within the river basin:

1. Export values allow to assess the human contribution to the contaminant loading of receiving water bodies;
2. Export values allow to identify critical territories in respect to loading;
3. Excessive export of substances can be an indicator to take measures to reduce loading by applying management methods.

Export of COD varies between river basins in Latvia by nearly twice (from 5226 kg km^{-2} year^{-1} for the Mūsa River up to 12731 kg km^{-2} year^{-1} for the Iecava River, both rivers of the Lielupe basin. The highest values of COD export evidently are due to agricultural activities and a high percentage of wetlands in the basin. The lowest COD export values are more usual for highly forested river basins. High specific loading of organic substances is contributed by the Salaca River basin. The basin of this river has a relatively high coverage of peat bogs, and waters of the river originate from the eutrophic Lake Burtnieks. However, the runoff of substances from domestic and non-point sources for this river are among the lowest of the studied river basins in Latvia.

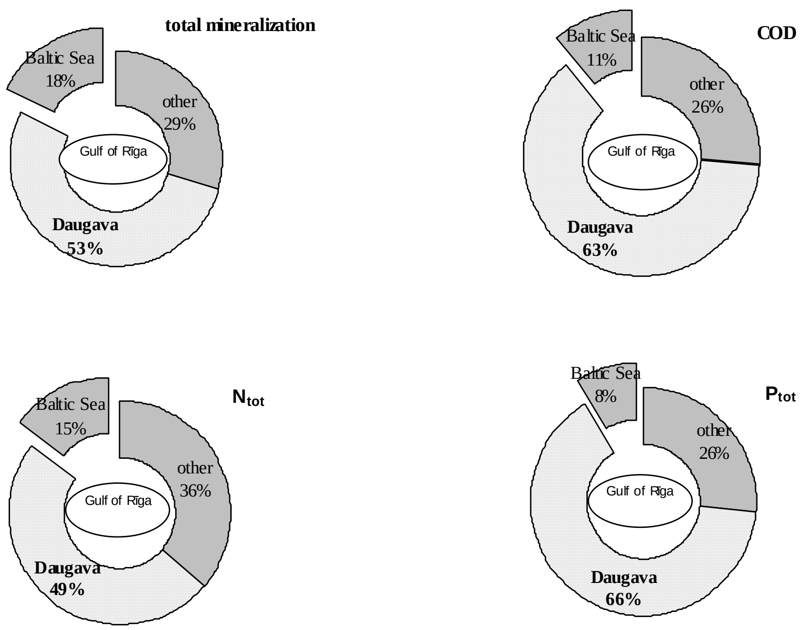


Figure 6.2. Relative proportion of loading from the territory of Latvia to the Baltic Sea and Gulf of Rīga.

Table 6.1. Runoff of dissolved substances from territory of Latvia (1977-1997, tons $year^{-1}$)

To the Gulf of Rîga:

River	COD	$N\text{-}NH_4^+$	$N\text{-}NO_2^-$	$N\text{-}NO_3^-$	PO_4^{3-}	P_{tot}	Total mineral.	HCO_3^-	SO_4^{2-}	Cl^-	Ca^{2+}	Mg^{2+}	Na^+	K^+
Daugava	680885	4096	315	21122	789	1168	5383084	3130401	547467	235631	887189	223671	152663	57490
Gauja	81770	424	25	3282	67	83	833091	470973	87281	27744	139663	39256	28561	7363
Lielupe	133113	1247	82	1054	282	324	1642206	826882	339455	86039	305154	71929	44473	14661
Salaca	35535	126	11	1275	18	23	300917	184167	30383	8791	53616	13248	3941	2269
Other	22471	309	13	1614	33	43	217166	114833	16876	10036	51132	18332	3718	2239

To the Baltic Sea:

River	COD	$N\text{-}NH_4^+$	$N\text{-}NO_2^-$	$N\text{-}NO_3^-$	PO_4^{3-}	P_{tot}	Total mineral.	HCO_3^-	SO_4^{2-}	Cl^-	Ca^{2+}	Mg^{2+}	Na^+	K^+
Venta	68363	455	28	5035	75	112	1059308	626352	111377	41150	184353	42953	20223	9538
Tebra	1379	19	2	57	5	8	14169	8131	1374	754	2428	519	502	137
Other	49940	280	14	1816	24	33	720760	472710	34911	58121	108002	31439	10051	5526

From territory of Latvia in total:

	COD	$N\text{-}NH_4^+$	$N\text{-}NO_2^-$	$N\text{-}NO_3^-$	PO_4^{3-}	P_{tot}	Total mineral.	HCO_3^-	SO_4^{2-}	Cl^-	Ca^{2+}	Mg^{2+}	Na^+	K^+
Gulf of Rîga	953774	6201	446	37833	1189	1640	8376465	4727256	1021463	368241	1436754	366436	233357	84022
Baltic Sea	119682	755	44	6908	103	152	1794237	1107193	147662	100026	294783	74911	30775	15202
Total	1073456	6956	490	44741	1292	1792	10170702	5834449	1169124	468267	1731537	441348	264132	99224

Table 6.2. Specific loading of dissolved substances from the territory of Latvia (1977-1997, kg km^{-2} $year^{-1}$).

River basin	COD	$N\text{-}NH_4^+$	$N\text{-}NO_2^-$	$N\text{-}NO_3^-$	PO_4^{3-}	P_{tot}	Total mineral.	HCO_3^-	SO_4^{2-}	Cl^-	Ca^{2+}	Mg^{2+}	Na^+	K^+
Daugava	9699	58	4.5	301	11.2	16.6	76682	44593	7799	3357	12,638	3186	2175	819
Gauja	9188	48	2.8	369	7.6	9.3	93606	52918	9807	3117	15,692	4411	3209	827
Lielupe	7563	71	4.7	599	16.0	18.4	93307	46982	19287	4889	17,338	4087	2527	833
Salaca	10390	37	3.1	373	5.3	6.7	87988	53850	8884	2571	15,677	3874	1152	664
Venta	8217	55	3.4	605	9.0	13.4	127321	75283	13387	4946	22,158	5163	2431	1146
Tebra	2484	35	2.9	102	9.8	13.7	25529	14650	2475	1359	4375	936	904	248
Other	6294	51	2.3	298	4.9	6.6	81530	51073	4502	5925	13,833	4326	1197	675
Average	7691	51	3.4	378	9.1	12.1	83709	48478	9449	3738	14,530	3712	1942	745

The variability of nutrient export is not as high as that of inorganic water ingredients. The differences between the highest and the lowest nitrate export values are by 4 times; and the variability for phosphate export is lower (with the exception of export from the Abuls River basin). Increased export of nutrients is associated with either intensive agriculture or large point sources (cities). The largest specific loads of nutrients are typical for the Lielupe, Daugava and Venta Rivers. In these river basins, agricultural production is intensive and settlements are abundant.

The variability of sulphate export is very high: from 3254 kg km^{-2} $year^{-1}$ for small rivers on coast of Vidzeme up to 32 668 kg km^{-2} $year^{-1}$ in waters of the Misa. However, the high values are difficult to link with human impacts, and geochemical processes seem to be the dominant factor driving sulphate variability: low concentrations of sulphate-containing minerals in soil throughout most of Latvia, and higher concentrations in the Lielupe River basin. Among the inorganic substances, the highest sulphate runoff occurs in the Lielupe River basin.

When the minerals supplying particular ions are fairly evenly distributed, then the variability of inorganic ions in water is much lower. This is the case for magnesium, calcium, chloride, sodium and potassium ions as well as particulate matter. However also for these substances, large differences between basins can be observed, and higher concentrations indicate regions where weathering processes are most intensive, such as in the Venta River basin. The major source of inorganic dissolved substances is natural weathering, and thus the loads of dissolved substances can be used to estimate the intensity of weathering.

Inorganic nitrogen (NH_4-N, NO_2-N, NO_3-N) and phosphorus (PO_4-P) are the main forms of the total nitrogen (55 % of N_{tot}) and total phosphorus (74 % of P_{tot}), respectively. Since the loading of dissolved substances from terrestrial sources is often contributed by human impact, then it would be useful in Latvia to study changes of nutrient loading in relation to the significant socio/economic development that has transpired in recent years. Studies by Laznik and Matisone (1994) and Stålnacke (1996) failed to find changes in nutrient loading between 1984 and 1994 in Latvia, which was surprising considering the major improvement in wastewater treatment and reduction in fertiliser application. On the other hand, evidence did suggest that nutrient concentrations in waters of the Gulf of Rīga were decreasing, along with associated changes in community structure. Knowledge of long-term changes of loading is important for understanding the processes that occur in surface waters.

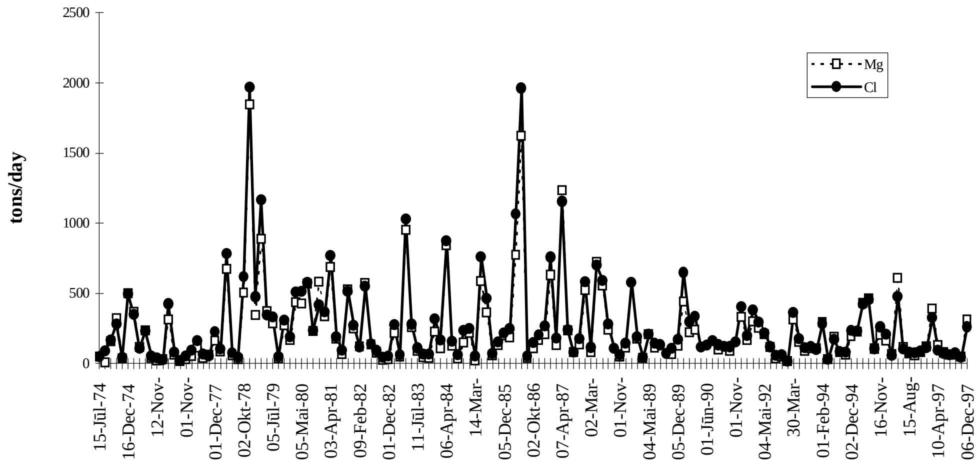


Figure 6.3. Long-term changes of loads of magnesium and chloride in runoff with waters of the Lielupe River.

In contrast to the nutrients, loading of Mg^{2+} and Cl^- is dependent on water discharge and natural geochemical processes (weathering of soil minerals etc.). The annual patterns of Mg^{2+} and Cl^-, and the increase observed between 1978 and 1988, are related to changes of water flow (Fig. 6.3.). Loading of mineral ingredients appears to be related to the nutrient loading (concentrations and loads of nitrate and phosphate). Increases in nitrate and phosphate concentrations occurred between 1978 and 1982, and between 1985 and 1992. Both of these maximum periods are associated with higher water discharge (Fig. 6.3.). Concentrations, as opposed to loading, seem to be less dependent on discharge than the loadings, and therefore are more suitable for investigation of long-term trends.

Waters of the Daugava River contribute the greater part of the metal loads from the territory of Latvia (Table 6.3.) to the Baltic, in part due to its greater water discharge. The Daugava River basin is the largest in Latvia, and actually covers territories in several countries (Latvia, Russia, Byelorussia, Lithuania). The river basin includes several big cities (Rīga, Daugavpils, Novopolotsk) that produce large amounts of pollution. Among the studied metals, the highest loads are observed for metals of presumably natural origin (Zn and Mn), and the lowest for cadmium. The origin of metals such as Cd, Pb, Cu, and Ni is mostly from anthropogenic sources.

Table 6.3. Metal discharges from the territory of Latvia (tons year^{-1}).

River	Cu	Pb	Zn	Mn	Cd	Ni
Daugava	26.6	5.1	87.9	56.3	1.1	11.2
Gauja	4.3	0.6	11.0	7.3	0.1	0.7
Lielupe	5.9	0.6	9.7	22.7	0.3	3.4
Salaca	2.1	0.5	3.2	2.4	0.1	0.2
Venta	3.8	0.7	9.1	19.6	0.1	1.0
Small rivers	2.5	0.3	5.7	13.1	0.1	0.7
Total	45.2	7.8	126.6	121.4	1.8	17.2

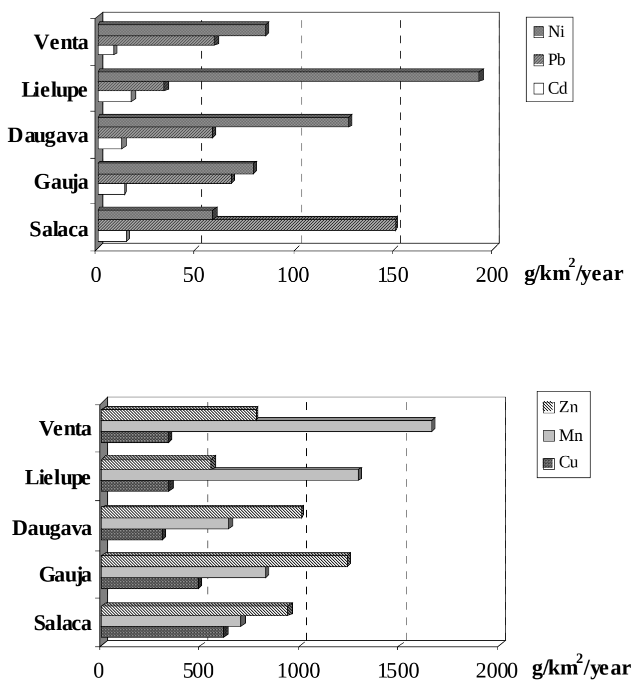


Figure 6.4. Specific loads of metals from the territory of Latvia, g km^{-2} year^{-1}.

Analysis of specific loads (g km^{-2} year^{-1}) of metals (Fig. 6.4.) allows evaluating the role of different processes in the catchment areas. In waters of rivers from western and central Latvia (Venta, Lielupe) the loads of manganese are higher than those of zinc, while in rivers from eastern Latvia (Salaca, Gauja, Daugava) zinc dominates over manganese. Also, the ratio of Ni/Cd loads considerably differs for rivers from eastern and western Latvia, indicating differing contamination sources.

6.2. Impact of cities on water quality in Latvia

Among different aspects of certain importance for studies of impact of cities on quality of surface waters can be considered upstream/downstream contaminant concentration analysis

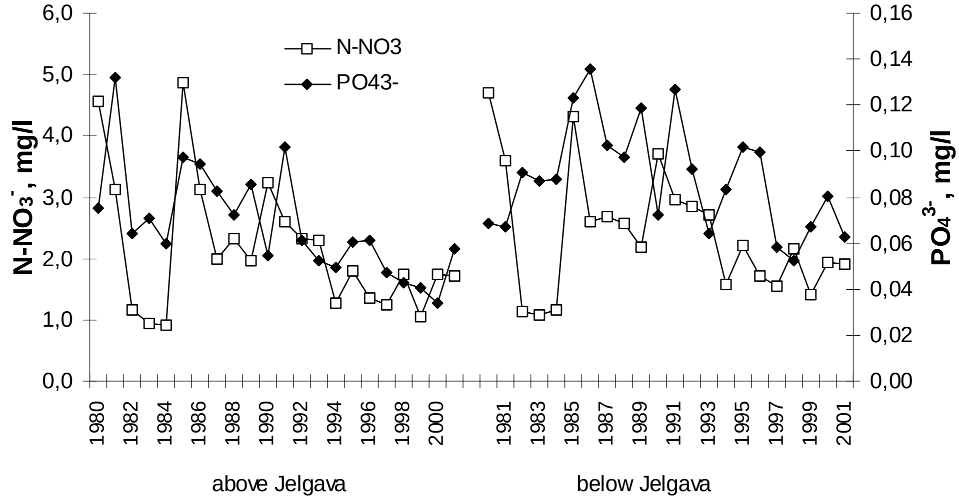


Figure 6.5. Changes of nitrogen mean concentrations in the River Lielupe above and below Jelgava (1980-2001).

However the analysis of single concentration data does not reveal the actual trends and impacts of cities as it is evident in case of River Lielupe water quality upstream and downstream Jelgava (Figs. 6.5., 6.6.).

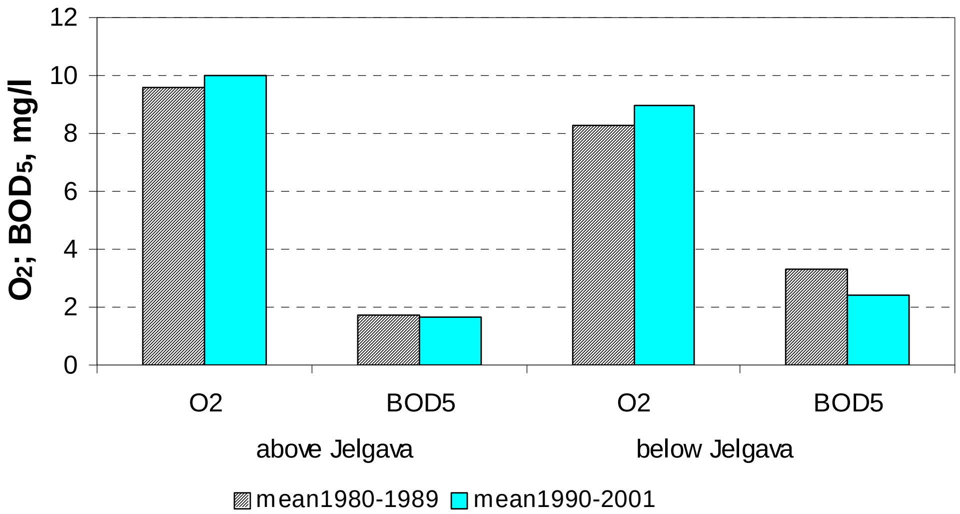


Figure 6.6. Changes of oxygen and BOD_5 mean concentrations in the River Lielupe above and below Jelgava (1980-2001).

Much more informative is evaluation of mean concentrations for a certain time period. As it can be seen from Figure 6.7 oxygen and easily degradable organic substances downstream the city are evidently influenced by the city. Similar impacts are also from Daugavpils (Fig. 6.8.).

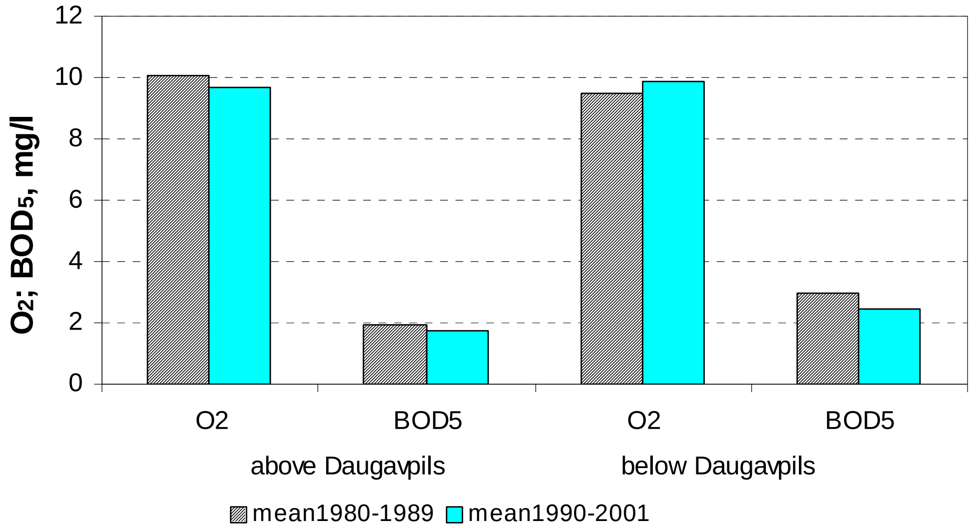
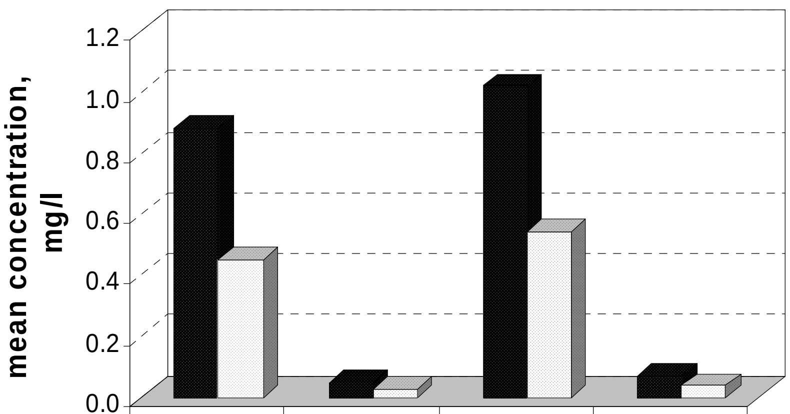


Figure 6.7. Changes of oxygen and BOD_5 mean concentrations in the River Daugava above and below Daugavpils (1980-2001).



	N-NO3	*PO43-*	*N-NO3*	*PO43-*
1980-1989	*0.882424242*	*0.049848485*	*1.02*	*0.071757576*
1990-2001	*0.449181818*	*0.028059091*	*0.54125*	*0.038638636*

a. Daugavpils **b. Daugavpils**

Figure 6.8. Changes of nitrogen mean concentrations in the River Daugava above and below Daugavpils City (1980-2001).

Similar impacts of cities are on concentrations of major nutrients, as it can be seen on example of nitrate and phosphate concentration changes in the Daugava River.

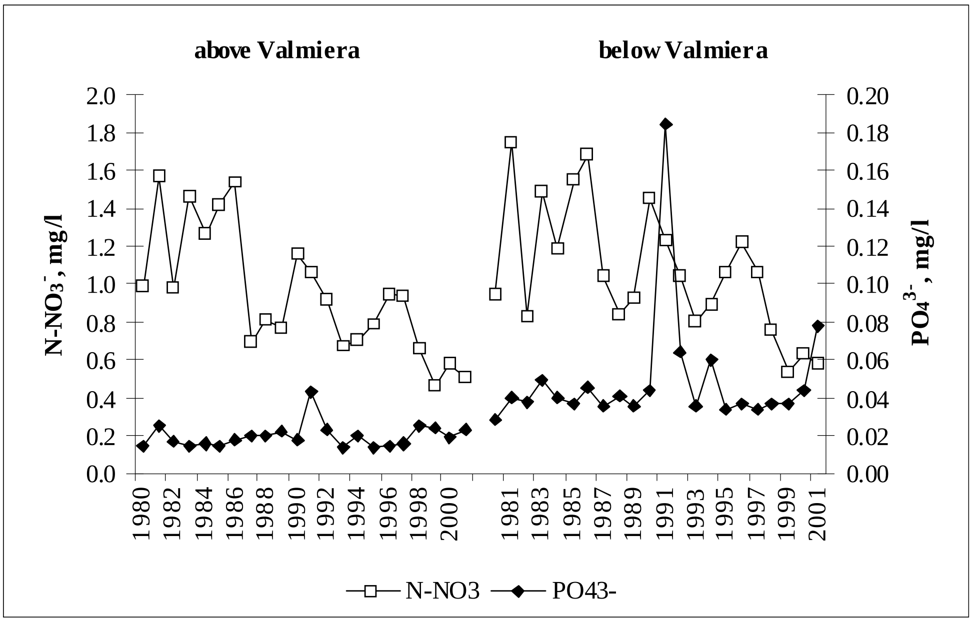


Figure 6.9. Changes of nitrate and phosphate concentrations in the River Gauja above and below Valmiera City (1980-2001).

In case of the River Gauja, which is comparatively less affected by human activities the impacts of Valmiera can be observed even by analysing actual monitoring data (Figs. 6.9., 6.10.).

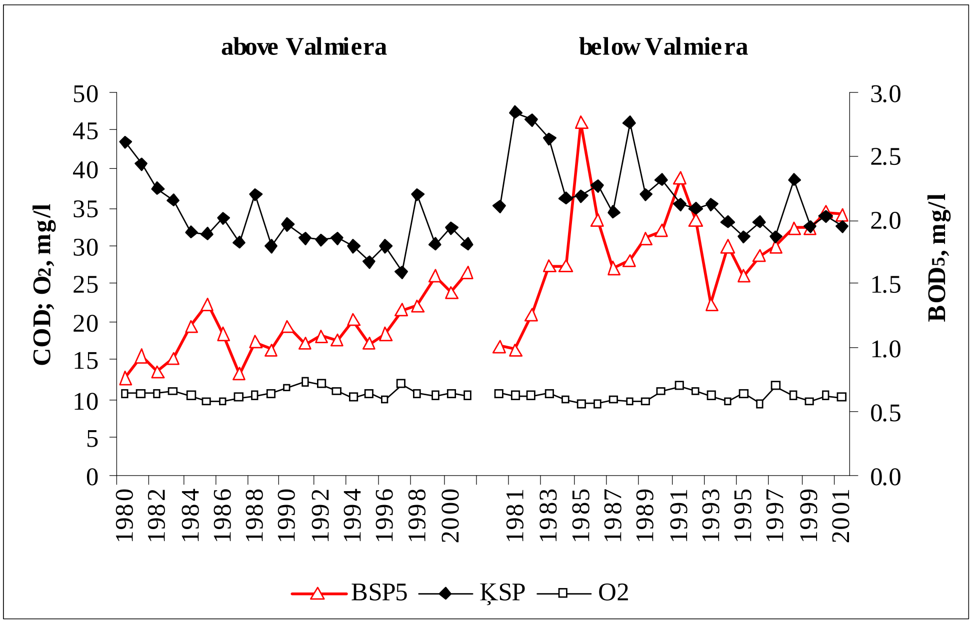


Figure 6.10. Changes of COD, O_2 and BOD in the River Gauja above and below Valmiera (1980-2001).

The impact of city can be directly observed as a significant increase of concentrations of both nutrients.

Long-term changes of chemical composition of the river waters in Latvia

7

Surface water quality is subjected not only to seasonal, but also to long-term fluctuations. Studies of long-term changes are important in the evaluation of changes in the environment. In Latvia, the recent years have witnessed a substantial reduction of human loads to the environment, due to transformation of political, economic and social systems. The transition processes are associated with recession in industrial and agricultural production (Fig. 7.1.).

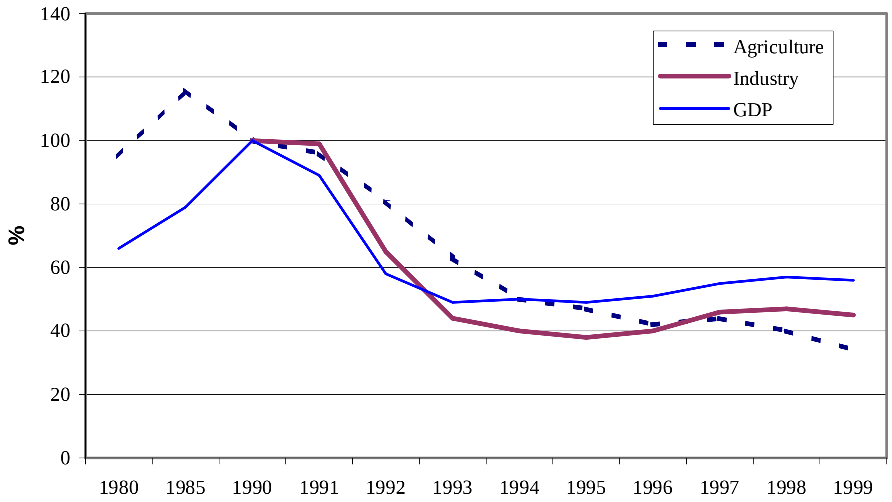
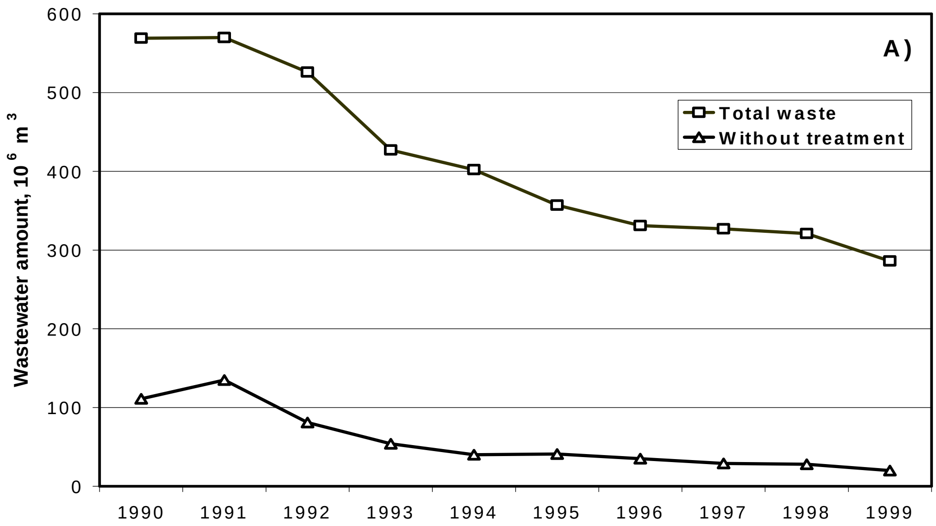


Figure 7.1. Relative changes of gross domestic product (GDP), and industrial and agricultural production of Latvia, 1980 = 100 % (Statistical Yearbook of Latvia 2000).



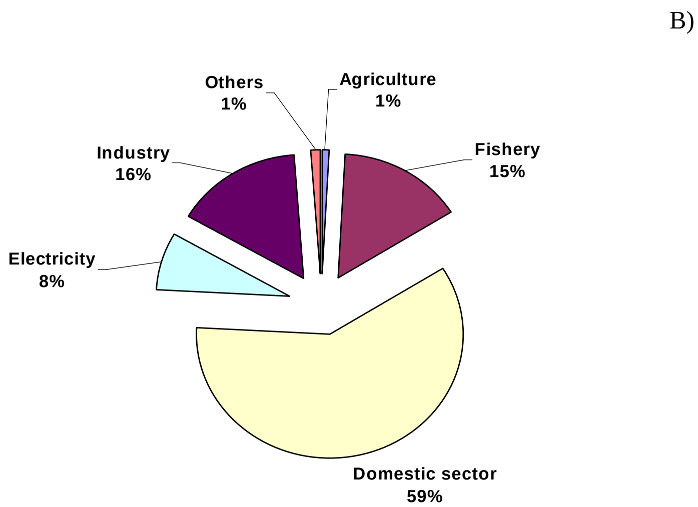


Figure 7.2. Wastewater amounts in Latvia (A) and distribution among the sectors in 1999 (B) (Statistical Yearbook of Latvia).

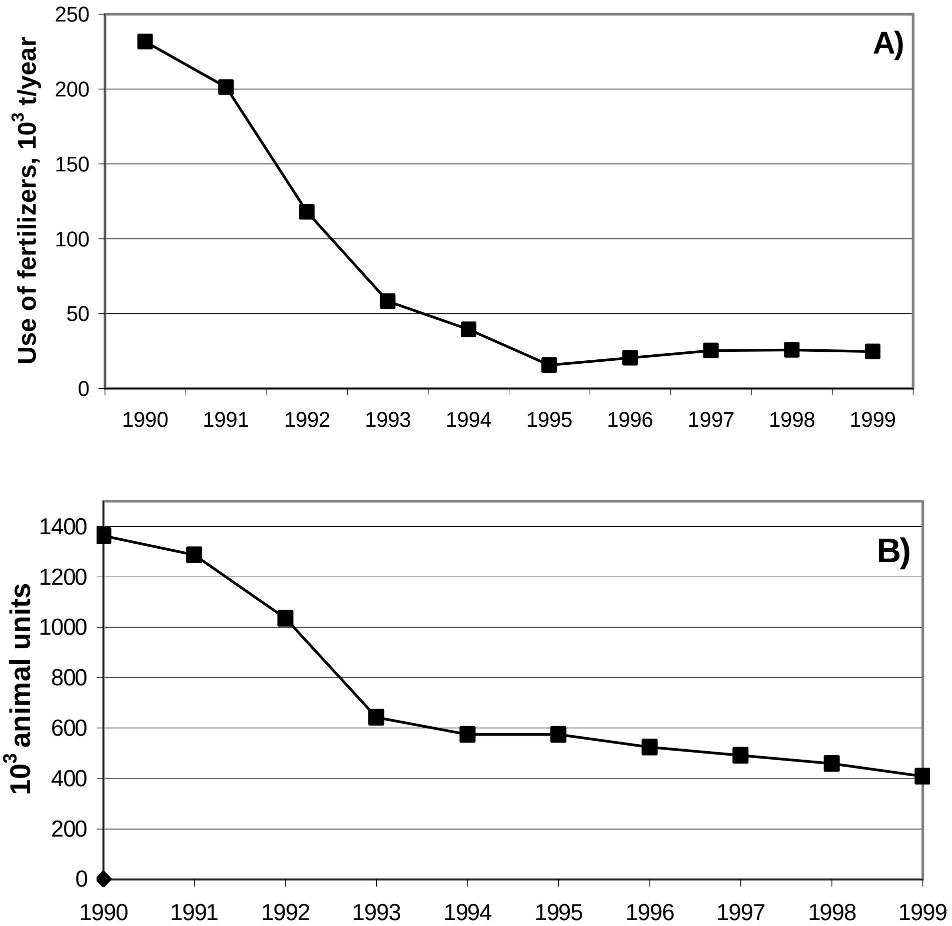


Figure 7.3. Changes in use of fertilisers (thousand tons N and P per year) (A) and livestock number (thousand animal units per year) (B) (Environmental quality in Latvia 2000).

For example, a substantial reduction of fertilizer use has occurred and number of livestock has decreased (Fig. 7.3.). During the economic transition, an environmental protection system has been developed according to tradition in West European countries, and this has acted to further decrease the pollution levels. Evidence of long-term changes of water chemical composition and its seasonal changes could be good indicator of the sensitivity of the existing National Monitoring Programme.

Trend analysis of water quality parameters identified increasing trends of Mg^{2+}, HCO_3^-, and SO_4^{2-}, indicating a more active role of carbonate mineral weathering processes (Fig. 7.4.). Decreasing COD trend is characteristic for the whole period of observations and thus cannot be associated with recent reduction of anthropogenic impacts. All trends of water chemical composition were tightly associated with changes in water flow. The observations mentioned above indicate that basic water chemical composition and its long-term changes largely reflect the intensity of natural processes, such as weathering of soils and minerals, and exchange with mineralised groundwater.

Analysis of $P\text{-}PO_4^{3-}$ and $N\text{-}NO_3^-$ concentration changes indicate commonly increasing trend till the years 1990-1992, but decreased trend afterwards (Figs. 7.5., 7.6.). It should be mentioned that occurrence of extreme values of nutrient concentrations has been decreased after the years 1991-1993, compared to the period 1977-1990. Thus clear dependence on changes in loading to inland waters is evident: increase till the years 1991-1993 and gradual decrease after 1992, when recession in industrial and agricultural production began.

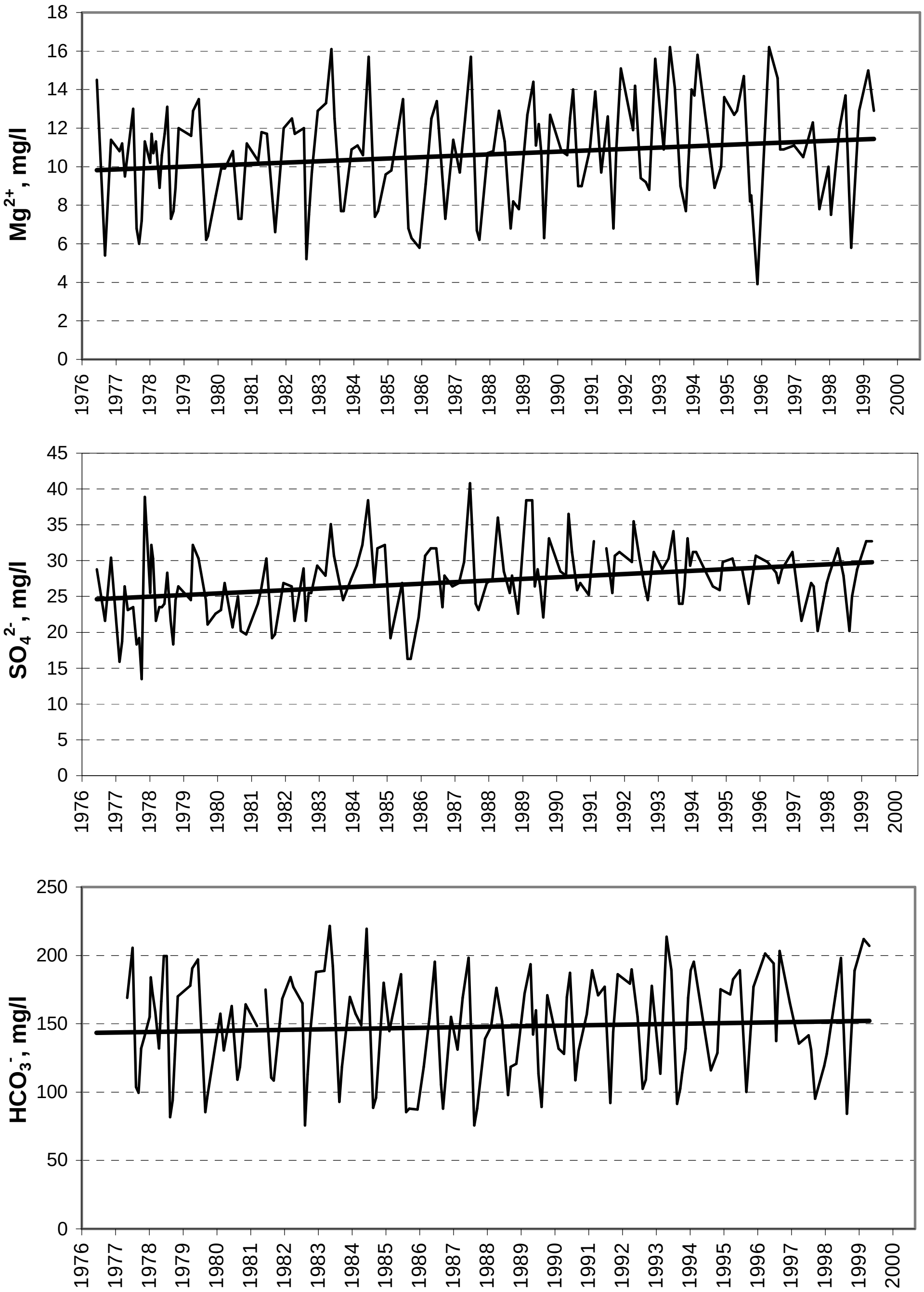


Figure 7.4. Long-term changes of Mg^{2+}, SO_4^{2-}, and HCO_3^- in the Daugava River at the sampling site Jēkabpils (1977-1999).

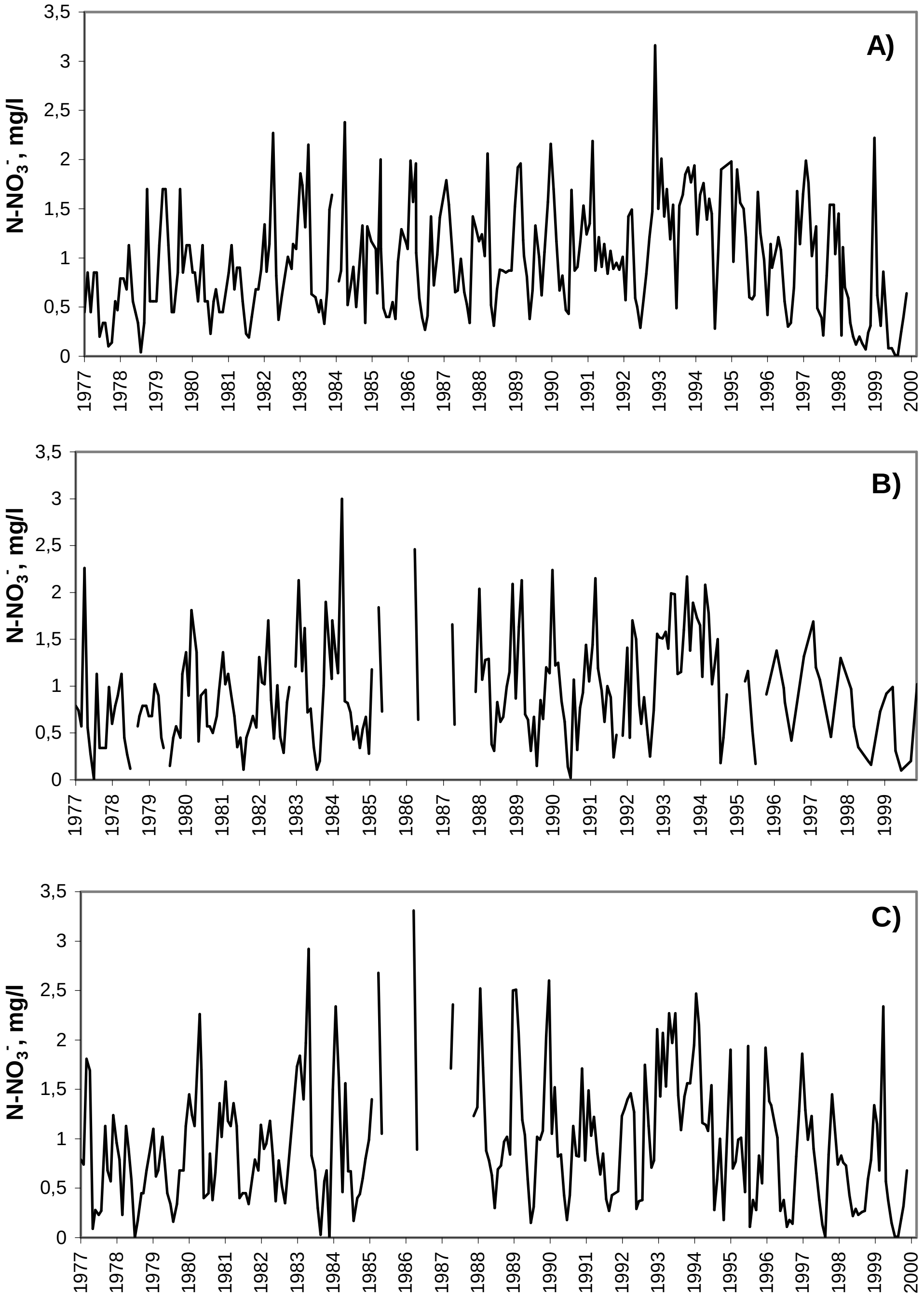


Figure 7.5. Long-term changes of N-NO$_3^-$ along the Daugava River: A- sampling site above Daugavpils, B- above Jēkabpils, C-sampling site at Lipši.

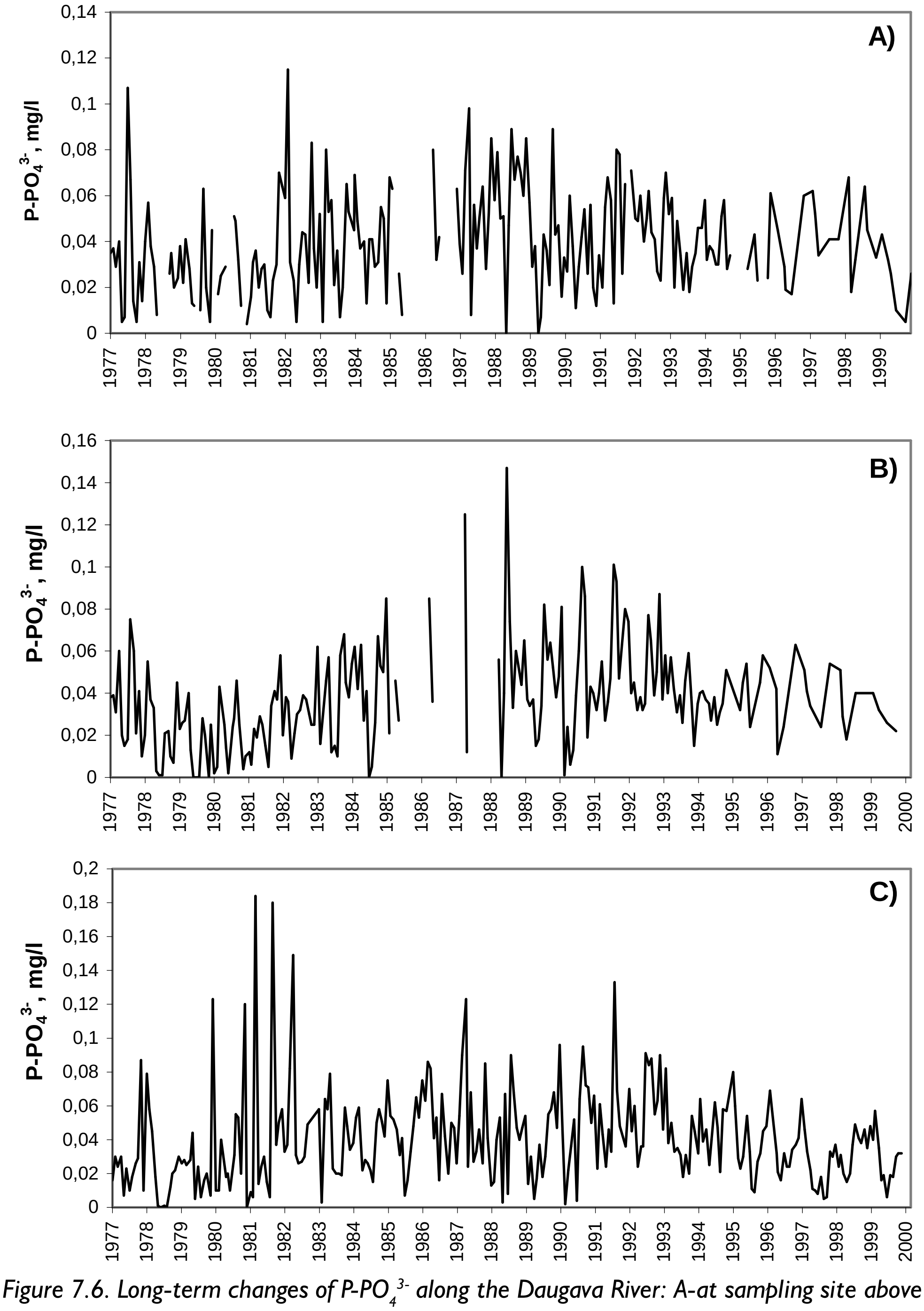


Figure 7.6. Long-term changes of $P\text{-}PO_4^{3-}$ along the Daugava River: A-at sampling site above Jēkabpils, B- above Aizkraukle, C- at sampling site Lipši.

Considering the dramatic decrease in agricultural production and drastic reduction of fertilizer use in the country, and also the installation of many new municipal wastewater facilities, different trends can be expected for changes of nutrient concentrations. However, this study revealed statistically significant ($p>0,05$) decreasing trends for nitrates only in two cases: on the Daugava River above Daugavpils and at the station Lipši (Table 7.1.). The failure of the reduction of nitrogen loading to influence directly nitrate concentrations in river waters may be due to slow mineralization of organic nitrogen bound in agricultural and forest soils (Stålnacke 1996). Another important factor may be exaggeration of fertilizer-use data during the Soviet rule. For ammonia, there are detected decreasing trends in five cases from ten, but for nitrites in six cases.

Analysis of phosphate concentrations revealed statistically significant decreasing trends in most of the cases. Similar pattern was also for total phosphorus concentrations.

This study did not reveal any significant trends for water discharge that is supposed to be significant factor influencing water quality.

Table 7.1. Mann-Kendall test statistics for the Daugava River basin, 1991.-1999. (Bold: $p > 0.05$)

Sampling station	Q	$N\text{-}NH_4^+$	$N\text{-}NO_2^-$	$N\text{-}NO_3^-$	$P\text{-}PO_4^{3-}$	P_{tot}
Daugava below Piedruja	-0.0344	**-2.5359**	**-2.4587**	-0.9631	**-1.6515**	1.3234
Daugava above Krāslava	-0.9266	-1.0301	-0.2608	0.3614	0.3156	0.8492
Daugava above Daugavpils	-0.3991	**-2.5784**	**-2.1302**	**-1.9424**	**-2.5541**	**-2.8300**
Daugava above Jēkabpils	-	**-1.6562**	**-3.7440**	-1.6117	**-5.3784**	**-2.3068**
Daugava above Aizkraukle	-0.6065	**-1.8859**	-1.1669	-0.5437	**-2.5169**	-0.3730
Daugava, Ķegums	-0.8012	-0.2674	**-1.7037**	-0.2243	-1.2237	-0.6617
Daugava, Lipši	0.3055	-1.4174	**-2.5753**	**-2.0996**	**-2.4135**	**-1.9242**
Dubna above Līvāni	-1.0773	-0.9751	-0.9466	-0.5731	**-2.2765**	**-2.5298**
Dubna below Līvāni	-1.2644	-1.4752	-0.9356	-0.2085	**-2.9251**	**-2.4681**
Aiviekste, mouth	0.1971	**-2.3492**	**-2.5476**	-1.2617	**-2.6369**	-

7.1. Changes of nutrient loads and retention proceses in the river basins

Quantification of nutrient retention as well as their spatial distribution in a river basin can be studied by different approaches. One simple approach is to study changes in the concentrations along the river stretch. Results from the Daugava River showed decreased total phosphorus concentrations from Piedruja (near the border to Belorussia) down to the mouth station at Lipši (Fig. 7.7. A). On the contrary, nitrogen concentrations showed an opposite pattern with higher concentrations at downstream sites (Fig. 7.7.B). Notable were also the apparent impacts from cities on the nutrient concentrations.

However, this kind of analyses gives quantitatively very little information about the retention. In addition, contribution from point sources and diffuse emission from land use between sampling sites can be significant and thus complicate the interpretation of concentration data at the various sampling sites and consequently estimation of retention.

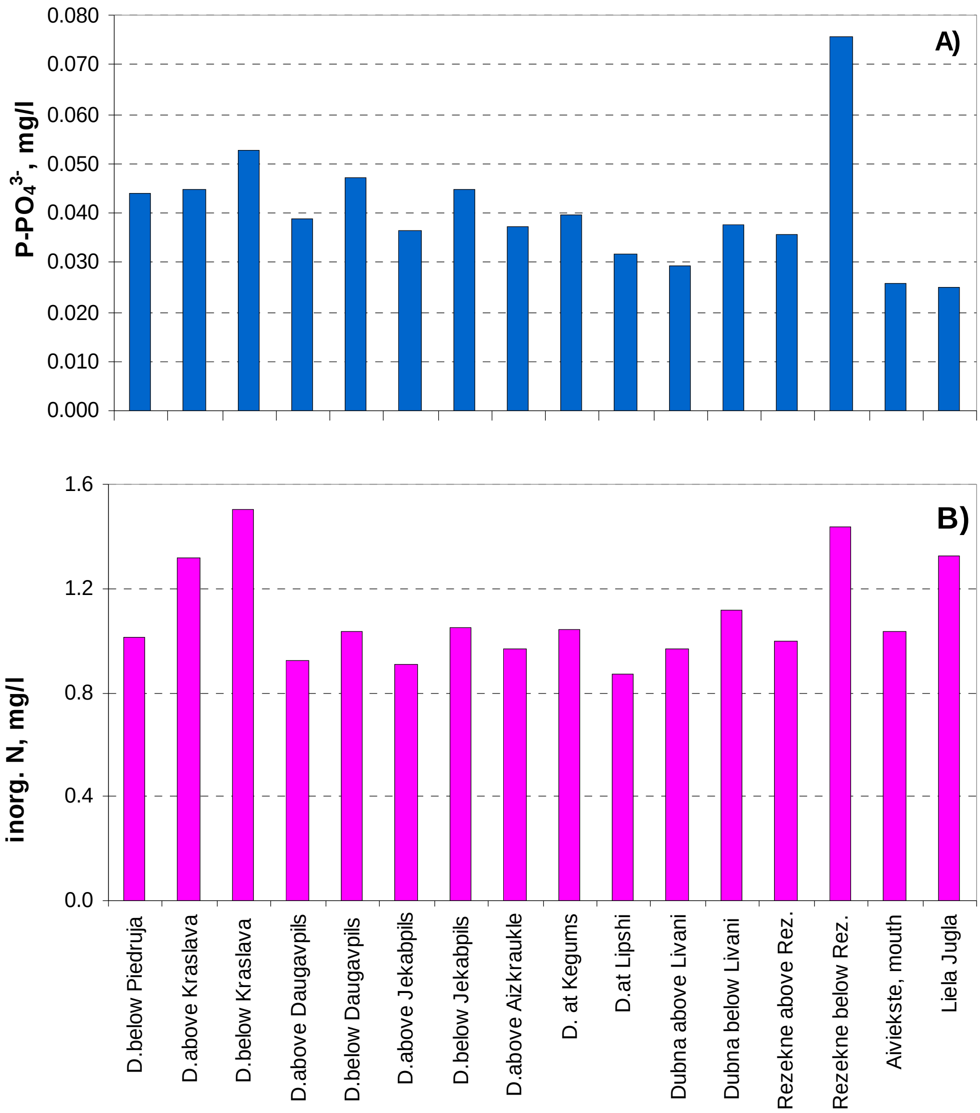


Figure 7.7. Mean concentrations of phosphorus and inorganic nitrogen in the Daugava River basin (1995-1999).

(mean concentrations for sampling site at Kraslava are given for time period 1993-1997)

In the Figs. 7.9. and 7.10 distribution of nutrient loads along the River Daugava flow is described. The calculations made allow analysing the most important sources and the actual fate of nutrients along the river flow. At first the high role of nutrients entering the territory of Latvia is evident (transboundary transport). Due to the transboundary transport the major loading takes place. At the same time it should be stressed that due to decomposition and involvement in biological processes much of nitrogen compounds are assimilated and transferred either to refractory organic matter either assimilated in biota. Thus, nutrients emitted in the territory of Latvia mostly reach the river mouth. Thus, the links with the need to implement a river basin management approach is evident. Major loading is coming in form of mineral nitrogen compounds, but among them major portion have nitrates. On the other hand, the calculations allow evaluating the relative impact of major cities. Influences coming with wastewaters from Krāslava, Daugavpils, Jēkabpils are high, but much less is the influence from Rēzekne, Līvāni and other smaller cities in the basin of the Daugava River. Of importance are also the loads originated from the tributaries and the results show a significant contribution.

In general, the contribution of nutrients from cities can be expressed as a difference between nutrient loads downstream and upstream the city. Regarding official statistics, the nutrient contribution from the Krāslava city (12 000 inhabitants) comprises 2800 t of inorganic nitrogen, but that for Daugavpils (115 000 inh.) and Jēkabpils (28 000 inh.) comprises 1800 and 2200 t of inorganic nitrogen per year, respectively ("Ūdens-2" 2000). However these estimations about point source pollution disaccord to those that are calculated using nitrogen emission coefficients. In general, this problem can be considered as one of the most important obstacles for application of statistical models like MESAW. There are several reasons for this. At first it should be stressed the quality of raw data, process of their accumulation and analysis. It is quite clear that governmental authorities have to do very much to provide decision-makers and researchers with relevant information. On the other hand, there it may be substantial problems about approaches used for calculation of loads based on number of inhabitants. This problem very much is associated with the actual estimation problem of loads considering the loading per capita. Actual is the analysis of efficiency of wastewater treatment plants and other processes. Evidently there is a strong need for future studies in this area.

Specific runoff shows nutrient load from given area unit (g km^{-2} $year^{-1}$). As it can be seen from figure 7.8., in the largest part of the Daugava River basin nitrogen loads vary from 300 up to 350 g km^{-2} $year^{-1}$. The highest values (500 g km^{-2} $year^{-1}$) of specific runoff were found in the Feimanka and Ogre Rivers. The highest phosphorus loads (more than 13 g km^{-2} $year^{-1}$) were found in the Rēzekne, Dubna and Ogre Rivers, but the lowest values in the Aiviekste and Lielā Jugla Rivers (Fig. 7.8.).

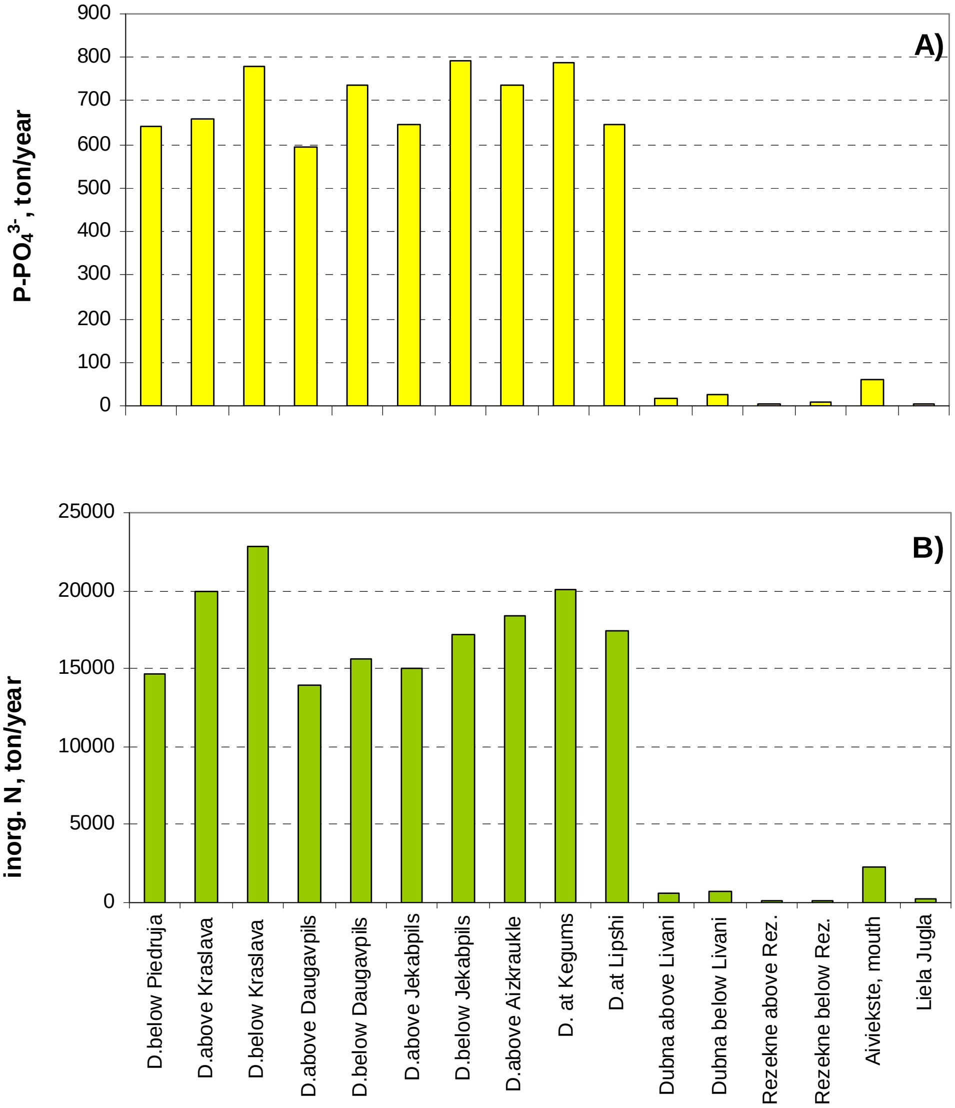


Figure 7.8. Average accumulated loads of inorganic nitrogen along the Daugava River and its tributaries (1995-1999).
(mean accumulated loads for sampling site at Kraslava are given for time period 1993-1997).

It should be mentioned that water quality sampling sites on the Dubna, Rēzekne and Ogre Rivers are located at the river mouth, up to 1.5km downstream the Līvāni, Rēzekne and Ogre cities, respectively.

Another important aspect includes the significant differences in the impacts of cities on surface water quality for periods of intensive human loading (period 1980 – 1989) in comparison with period when due to the restructuring of production intensive reduction of loading takes place (1990 – 2001). As it can be seen from all analysed situations major reduction of the loading takes place.

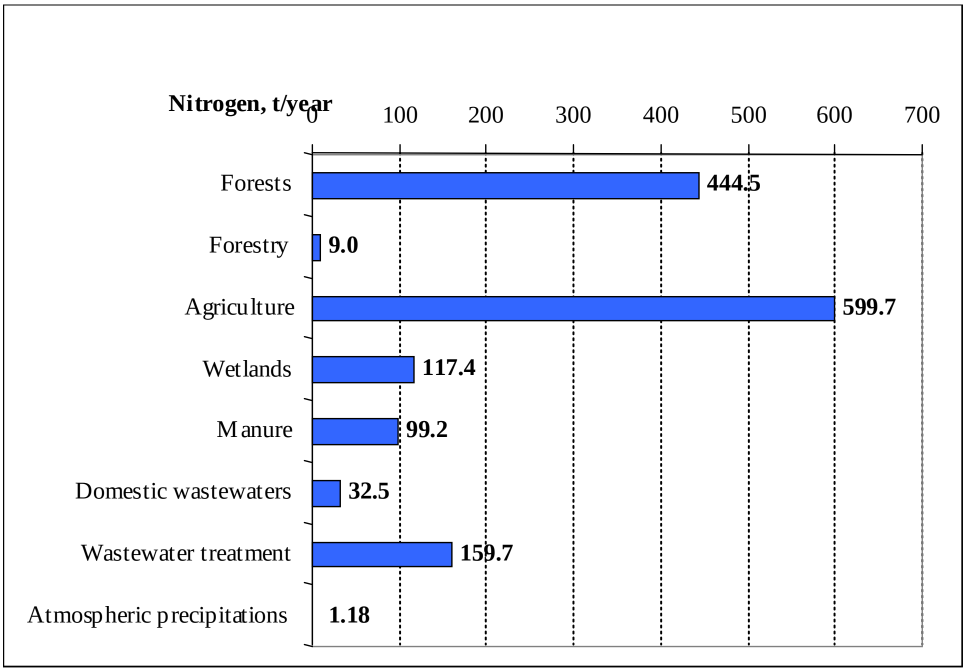


Figure 7.9. Distribution of N_{tot} sources in the basin of River Daugava

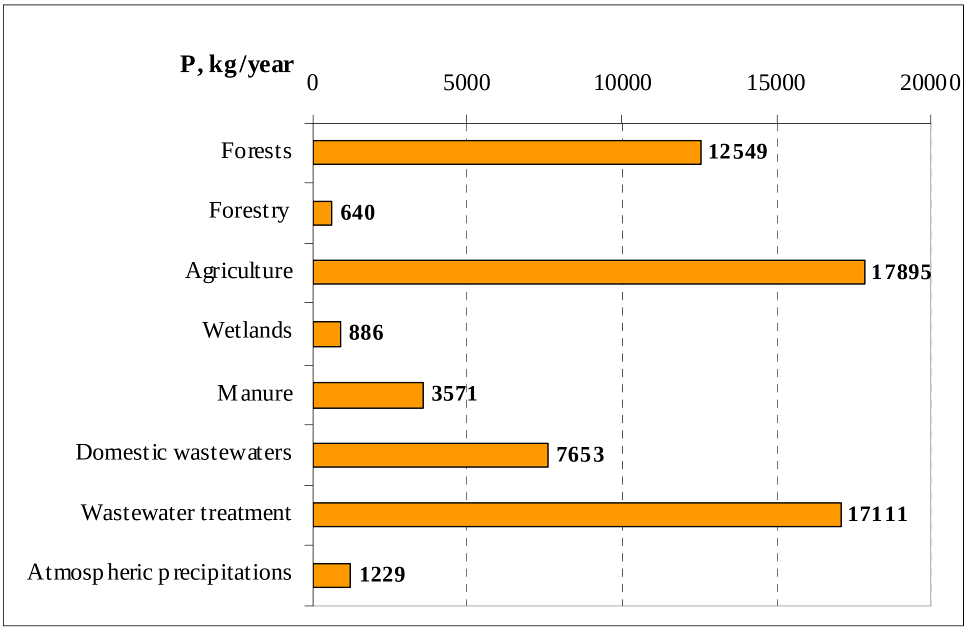


Figure 7.10. Distribution of P_{tot} sources in the basin of River Daugava

8 Modelling of nutrient flows in the River Aiviekste basin

8.1. Description of the River Aiviekste basin

The River Aiviekste basin (Fig. 8.1) encompasses rather large territory (9293 km^2) in Eastern Latvia, and it is a part of the River Daugava basin. The River Aiviekste basin consists of the River Aiviekste, Pededze and Rēzekne and two major lakes – Lubāna and Rāznas. To the East River Aiviekste basin borders with the River Velikaja basin, and to the North and Nortwest with the River Gauja basin.

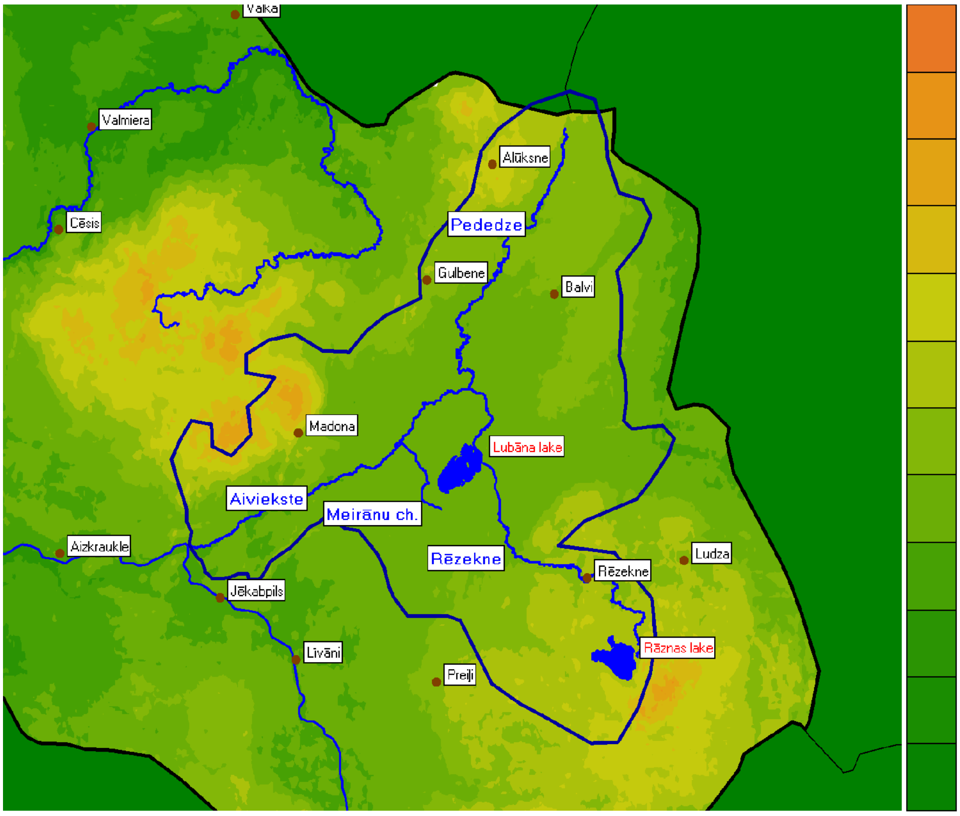


Fig. 8.1. The basin of the River Aiviekste. Digital terrain map with the main rivers and lakes.

The River Aiviekste is situated in the central part of the River Daugava basin, as well as at the Vidzeme upland and Eastern Latvian lowland. The River Aiviekste junction basin embodies Aizkraukle, Jēkabpils, Madona, Gulbene, Balvi and Rēzekne districts.

The basin of the River Aiviekste includes the basins of the River Pededze (1523 km^2) in the North and of the River Rēzekne (2022 km^2) in the East.

The River Pededze is the Northeastern branch of the basin. The River Pededze basin is situated in the Alūksne, Gulbene, Balvi and Madona districts. A rather insignificant northern part (25 km) of the River Pededze basin is situated in Estonia.

The River Rēzekne basin is situated at the northern part of the Latgale upland. Basin comprises Ludza, Preiļi and Krāslava districts. The River Rēzekne flows through the town Rēzekne. Most of the basin is situated on the northern slope of the Latgale upland, and only the lowest part of the river is situated at the Lubāna lowland.

The River Aiviekste basin contains also two rather big lakes: Lubāna and Rāznas. The Lake Lubāna is situated approx. in the middle of the basin system, and in the middle of the Lubāna lowland. The River Rēzekne borns from the Lake Rāznas.

Geology

The River Aiviekste basin is situated mostly on the Vidzeme upland southern slope, Vestienes hummocky and East Latvia lowland. The River Pededze flows in the Northwestern part of the Eastern Latvia lowland.

Geological setting at the **River Aiviekste basin** can be characterized by the upper Devonian sandstones, siltstones, clays, dolomites and dolomitic marls, which are covered by up to 15 m thick quaternary deposits e.g. glacigenic or glaciolacustrine sediments. Network of the buried ancient valleys triggers the geomorphology of the modern river valleys and other placement of negative terrain.

The **River Pededze** is situated at the Northeastern part of the East Latvia lowland. In the territory of Latvia it starts to flow from the Alūksne upland, which is formed of the upper Devonian carboniferous and terrigenous material. The thickness of the quaternary sediments is approximately 20 – 40 m at the upland area and these sediments are composed mostly of glacigenic and glaciofluvial material. The thickness of the quaternary deposits is lower at the lowland, and these sediments are composed mostly of glacigenic till sediments, covered by the glaciolimnic fine sediments. River Pededze partly flows above the buried valley, average thickness of the quaternary sediments in the valley is 40 – 60 m.

The River Rēzekne is situated at the Eastern Latvia lowland, and Latgale upland. Quaternary sediments on the upland are up to 100 m in thickness and they are composed of the glacigenic deposits. The thickness of the quaternary sediments is up to 10 m in the lowland area, and they are composed of glacial till, which is covered by the glaciolimnic sediments.

Hydrology

The River Aiviekste is the right bank tributary of the River Daugava. It runs from Lake Lubāna. The River Aiviekste basin (together with the rivers Pededze and Rēzekne basins) occupies the area of 9293 km^2.

The River Aiviekste passes through the Lubāna lowland, then it crosses Arona hummocky lowland and finally it flows into the River Daugava at the Viduslatvijas lowland.

The length of the River Aiviekste is 118 km. The width of the River Aiviekste is approx. 70 – 90 m and it reaches average 3.5 – 4 m depth at the downstream stretch (upstream the Rīga – Daugavpils railway, i.e. above the influence of the Pļaviņas HPP). In the middle stretches, nearby the River Kuja junction, the River Aiviekste is up to 40 – 50 m wide and 2 m deep. Aiviekste is 30 – 35 m wide and 1.5 – 2 m deep in the upstream stretches nearby the River Iča junction.

The River Aiviekste annual mean flowrate at the river's outlet from the Lake Lubāns is 12.8 m^3 s^{-1}, downstream it reaches 30.3 m^3 s^{-1} at the Lubāna town, 57.8 m^3 s^{-1} at the Aiviekste HPP, and 60.2 m^3 s^{-1} inflowing into the River Daugava.

The flow of the River Aiviekste is rather slow from the outlet in the Lake Lubāna down to the entry of the Meirānu channel. Current velocity during the summer periods may be as low as 0.15–0.2 m s^{-1} The right bank tributaries, the rivers Iča and Balupe are also slow, lowland type rivers, especially in their lower reaches.

The velocity of the river current increases further downstream, and near Ļaudona town it reaches 0.25-0.3 m s^{-1}. It slows down due to the Aiviekste HPP dam, but after the dam until the railway bridge current velocity increases up to 0.4-0.5 m s^{-1}. The outlet of the River Aiviekste is at 92.5 m a.s.l, but the entry in the River Daugava nearby the town Pļaviņas is 72.0 m a.s.l.

Right bank tributaries of the River Aiviekste (Pededze, Liede, Kuja, Arona, Veseta) flow mostly from the Vidzeme upland, and they may be characterised as the fast flowing rivers. Tributaries at the river's upper part (Balupe and Iča) as well as the left bank tributaries are much slower, these rivers can be characterized as typical lowland rivers. The artificial Meirānu channel should be considered as the biggest left bank tributary. It collects waters from the most of the southern part Lubāna lowland (rivers Kažauka, Lisiņa, Malmute etc.), as well as it drains a part of the lake Lubāns. A big part of the Lubāna lowland rivers were diverted directly into river Aiviekste by this channel to regulate the level of the Lake Lubāns. As a result these rivers were straightened and deepened. Such rivers are Teicija, Malmute, Lisiņa, Kažauka, Komorsta and others.

Urbanisation

There are aproximately 1500 inhabited localities in the River Aiviekste basin. The total of approx. 172000 inhabitants live in the catchment area. Approx 30 % of these inhabit the biggest towns: Rēzekne, Madona, Balvi, Alūksne and Gulbene.

Territories at risk of flooding

The territory of Lake Lubāna is considered as one of such areas in the National flooding risk map. It encircles the upper reaches of the River Aiviekste, which together with the Lubāna lowland creates a natural depression. The flooding was rather frequent (annual snow melt flood) before the construction of the dams across the Lake Lubāna.

Hydropower plants

Only one HPP is operating on the main River Aiviekste, approximately 15 km upstream the junction into the River Daugava. In total, 8 small HPP can be found on its minor tributaries (excluding the Pededze and Rēzekne river basins). There are two HPP operating on the River Pededze. Two small HPP are renovated on the River Rēzekne and three on the River Malta in the Rēzekne river basin.

Land use

Let us consider only the main three land-use types – forests and bushes, rural areas, and other (incl. urban) areas. Then their division for the main subbasins is as follows:

- The main Aiviekste river basin 48%, 47%, 5%.
- Pededze river basin 58%, 41%, 1%.
- Rēzekne river basin 62%, 34%, 4%.

8.1.1. Approach to the modelling

There are several possible approaches to the mathematical modelling of the hydrological processes in the catchment of the river. The ***physically-based spatially and temporally distributed dynamic modelling*** was chosen for this study. Thus, the process-resolving representation of the basin hydrology and atmosphere-land interaction was used. The catchment was divided into hierarchical subbasins downscalable up to finite element level.

The hydrological cycle was resolved for the lowest hierarchical level, the hydrological cycle modelling was coupled with the dynamic routing of the water flow through the network of streams.

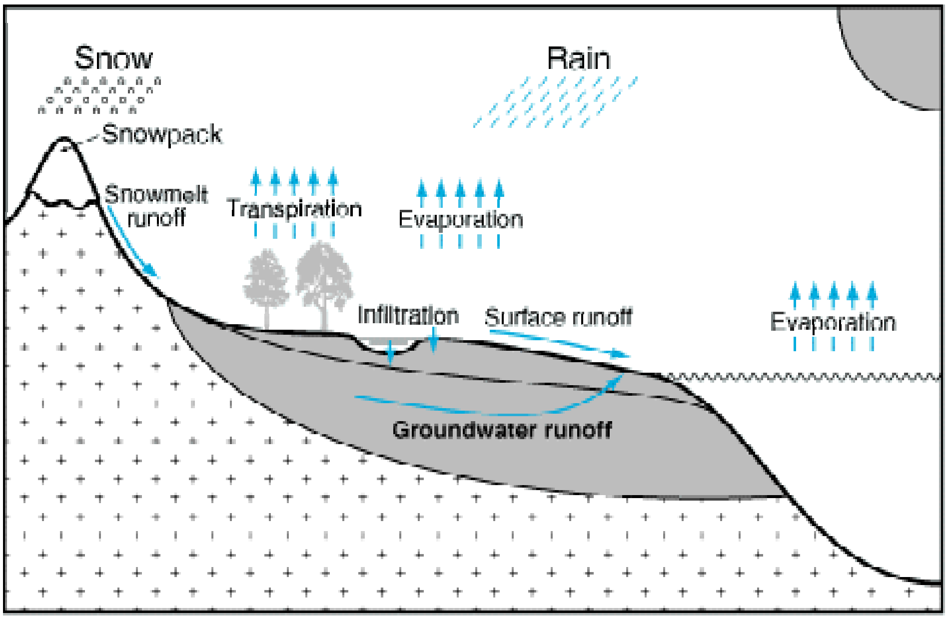


Fig. 8.2. Scheme of processes considered for hydrological modelling

Spatial distribution of topography and river's network, spatial and temporal distribution of precipitation (rainfall, snowfall), meteorology, soils, vegetation (and use) was required for the description of the processes (Fig. 8.2).

The model was forced by the meteorological data, and calibrated/verified against the available observation data.

8.2. Hydrological modelling of the River Aiviekste catchment

Mathematical model

The physically based spatially and temporally distributed dynamic modelling approach was used, following the ideas of Chow *et al.* (1988), USACE (1994). The model system consists of the coupling of 5 different models:

- model of the surface water content;
- model of the snow accumulation and melting;
- model of the groundwater flow;
- dynamic flow routing model;
- lake model.

The finite element method is used for all models. The scheme of the finite element mesh is shown in Fig. 8.3. The formulations of the particular mathematical models may refer to this Figure. Surface water and snow balance is calculated for the finite elements, the elevation, lake and the groundwater levels are defined in the finite element nodes, and the rivers (streams) always coincide with the edges of the finite elements.

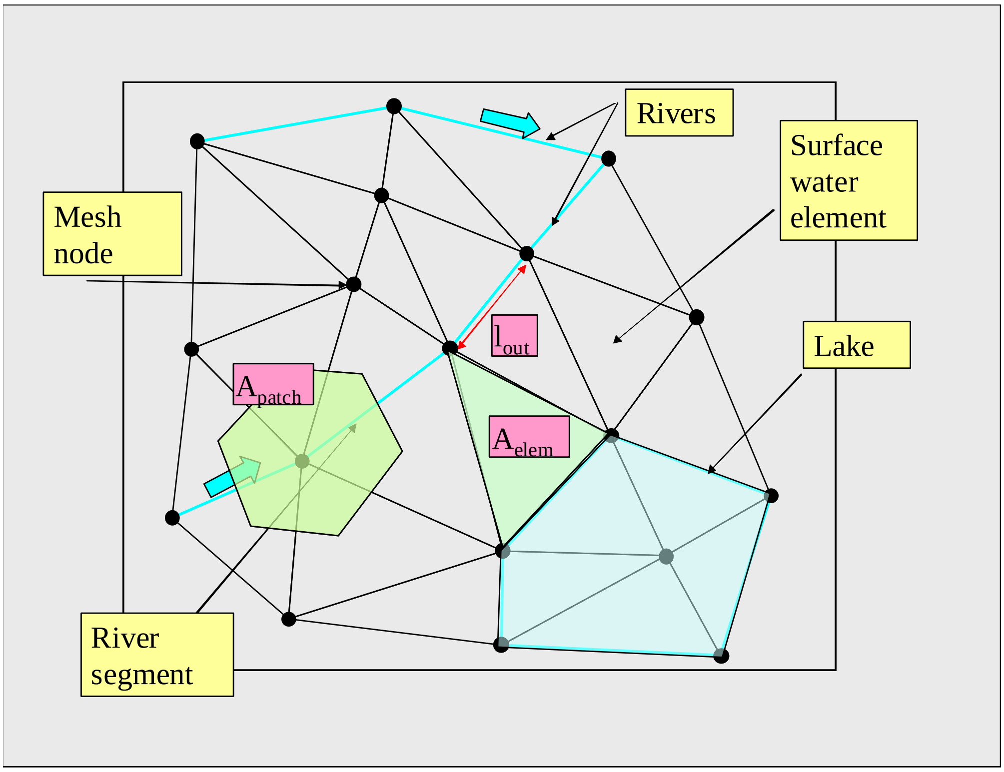


Fig. 8.3. Finite element mesh and the elements of the modelling system.

The ***surface water model*** solves the equation

$$\frac{dw}{dt} = P - E - V_{\inf iltr} + V_{surface} - \sum_i V_{runoff}^{-(i)} + \sum_i V_{runoff}^{+(i)} + V_{snow} \qquad (1)$$

for the intercepted + ponded water content w. (1) is solved (i.e. w is defined) for the surface water finite elements (see Fig. 1). The right-hand-side of (1) contains the following elements of the surface water balance:

1. Precipitation in a form of rain P.
2. Evapotranspiration E. We use the following parameterisation of the evapotranspiration:

$$E = K_e(w)(e_{sat}(T) - e) \qquad (2)$$

Here e and e_{sat} are water vapour partial pressure and its saturation value, whilst K_e is a coefficient dependent on the land use, vegetation and the presence of snow.

3. Velocity of the infiltration $V_{infiltr}$ depends on the surface water content, groundwater level and the presence of the snow.
   3.1. The infiltration V_{infilt}=0 if the groundwater level reaches the surface (h³z) or the surface water content is below the intercepted water content (w£$W_{intercepted}$).
   3.2. The infiltration velocity is at the minimum value ($V_{infiltr}$=V_{imin}, V_{imin} is the calibration parameter) during the presence of snow (V_{snow}>0).
   3.3. The infiltration velocity is at the maximum value ($V_{infiltr}$=V_{imax}, V_{imax} is the calibration parameter, both V_{imin} and V_{imax} depend on the land use) if the snow is absent.
4. The groundwater saturation excess flow $V_{surface}$ is given by

$$V_{surface} = (1-\alpha_s)\frac{K(h-z)}{\Delta l_{surface}} \tag{3}$$

Here K is hydraulic conductivity of the soil, $\Delta l_{surface}$ is the empiric parameter. The outflow to the surface water occurs only if the groundwater level exceeds the surface elevation (h>z). The part $0<a_s<1$ of the groundwater outflow is assumed to freeze (i.e. add-up to snow volume) during the winter time (i.e. negative air temperature).

5. The overland flow to/from the neighbouring (i^{th}) elements is given by

$$V_{runoff} = \frac{1}{n}\left(w - w_{intercepted}\right)^{2/3} S_0^{1/2} \cdot \frac{l_{out}}{A_{elem}} \tag{4}$$

Here n is the land-use-dependent Manning coefficient for the overland flow, S_0 is the surface slope (of the finite element), A_{elem} is the element area, and l_{out} is the length of the considered edge of the finite element (see Fig. 1). The overland flow direction is determined by the surface slope.

6. V_{snow} is the snow melting rate.

The model for the ***snow melting and accumulation*** is adapted from Zīverts and Jauja (1999). It solves the equation for the balance of the equivalent water content S accumulated in a form of snow:

$$\frac{dS}{dt} = P_s + \alpha_s \frac{K(h-z)}{\Delta l_{surface}} - V_{snow} \tag{5}$$

The right hand terms in (5) correspond to

1. P_s is a precipitation in a form of snow.
2. The part of the groundwater excess flow (if, any, see (3) above).
3. V_{snow} is a degree-day dependent snow melt rate which accounts for the incoming solar radiation I (Zīverts and Jauja 1999)

$$V_{snow} = C_{melt}(T - T_2) \quad C_{melt} = C_{meltB} + A_{melt} I \tag{6}$$

here $T_2>0$ is a reference temperature, C_{meltB} and A_{melt} are the model parameters.

The 2D ***groundwater flow model*** considers the piezometric head (or groundwater level) h of the upper aquifer, see also USACE (1998). The groundwater level is defined at the nodes of FE mesh (see Fig. 1), and the balance equation stands as

$$(h - z_g)S_s \frac{\partial h}{\partial t} = \nabla \cdot \left(K(h - z_g)\nabla h\right) + V_{infiltr} - V_{river} - V_{surface} \tag{7}$$

here z_g is the level of the aquitard, and S_s is the soil storativity. The right hand terms of (7) correspond to, respectively:

1. Groundwater filtration according to Darcy law.
2. Infiltration from the surface water, see p.3 above.
3. Outflow to rivers V_{river} at the river nodes (see Fig. 1):

$$V_{river} = \frac{K(h - h_{river})}{\Delta l_{river}} \tag{8}$$

here h_{river} is the water level in the river node, and Dl_{river} is a calibration parameter.

4. Groundwater outflow to surface water $V_{surface}$ is given by (3) above.

The groundwater model is closed by the external no-flow conditions on the outer boundaries, whilst $h=h_{lake}$ is set for the lake nodes (see Fig. 1).

The dynamic ***flow routing model*** solves for the time development of the water level h_{river} and discharge Q on the staggered finite difference grid along the rivers. Water level is defined at the model nodes, whilst discharge at the river segments (Chadwick and Morfett 1994), see also Fig. 1. The full St. Venant equations are solved

$$\begin{cases} \frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = q \\ \frac{\partial Q}{\partial t} + \frac{\partial(\beta Q^2 / A)}{\partial x} + gA\left(\frac{\partial h_{river}}{\partial t} + S_f\right) = 0 \end{cases} \tag{9}$$

here A is the river cross-section area (we use assumption of the parabolic river profiles providing the river bed level from the digitised topographic maps), x is a distance along the river, and q is the source term

$$q = \sum_i V_{runoff}^{+(i)} \cdot l_{out(i)} + \sum_i V_{river} \cdot \frac{A_{patch}}{l_{out(i)}} \tag{10}$$

accounting for the surface runoff and groundwater discharge into rivers. The bed friction term in (9) is given by

$$S_f = \left(\frac{nQP^{2/3}}{A^{5/3}}\right)^2 \tag{11}$$

here P is wetted perimeter.

The ***lake model*** solves the dynamic balance of the water level h_{lake} in the lakes

$$A_{lake}\frac{dh_{lake}}{dt} = \sum_i Q_{riverin}^{(i)} - \sum_i Q_{riverout}^{(i)} + \sum_i V_{runoff}^{(i)} l_{out}^{(i)} (w - w_{intercept})^{(i)} + \\ + \oint_\Gamma K \frac{\partial h}{\partial n}(h - z_g) d\Gamma + P - E \tag{12}$$

here A_{lake} is the lake surface area, and the right-hand-side terms in (12) correspond to river in- and outflow, surface runoff, groundwater in/outflow, precipitation and evaporation.

8.3. Input data

As input data for modeling following information was used:

1. The ***digital terrain map*** and the river network were used to create the model grid including surface elevation, the model river network, and the definitions of the lake boundaries. The calculation mesh and river network is shown in Fig. 8.4.

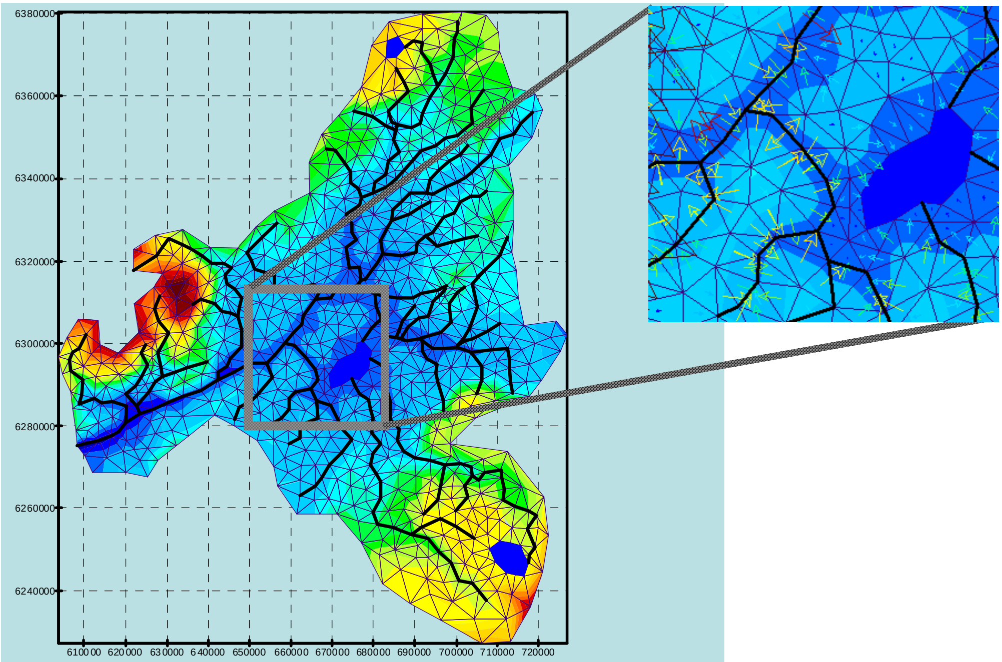


Fig. 8.4. The finite element mesh and river network used for the calculations.

2. The ***land use*** data was interpolated on the calculation mesh. The fractions of 6 different land use types (agricultural, forests, bushes/grasslands, swamps, artificial and waterbodies) were calculated for each finite element. The examples for the distribution of the area percentage of the forests and agricultural lands are shown in Fig. 8.5. One may consider that the forests are rather representative land-use type in the basins of Aiviekste itself and of the River Pededze (northern part of the basin), whilst the agricultural lands prevail in the basins of Malta and Rēzekne rivers (southeastern part of the catchment).

3. The observations of the ***river discharge*** were taken from Zīverts (2000). We used 7 hydrometric stations in this report (see Fig. 8.6.).

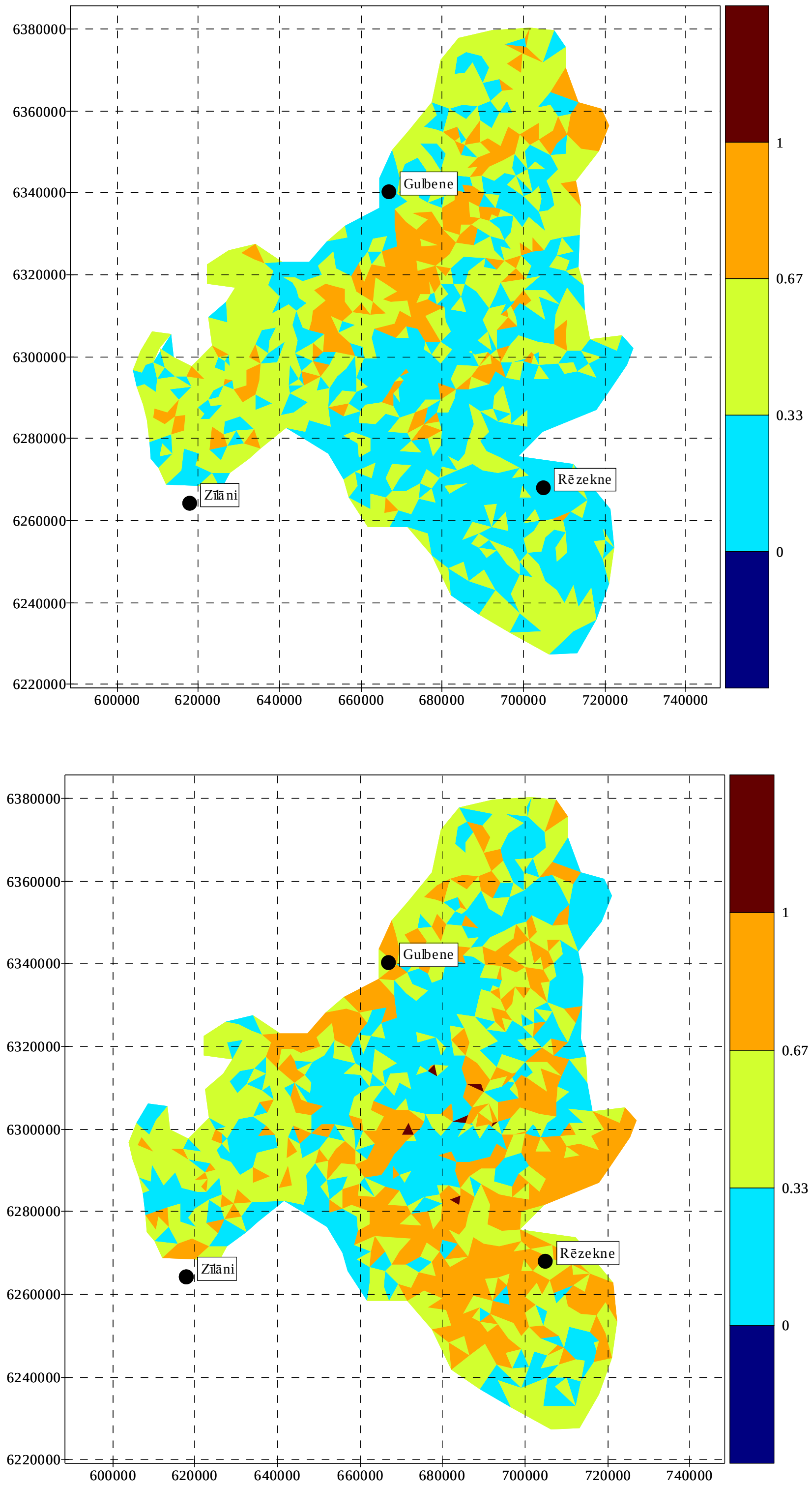


Fig. 8.5. The distribution of the area percentage of different land use types: forests (left) and agricultural lands (right). The location of the meteorological observation stations.

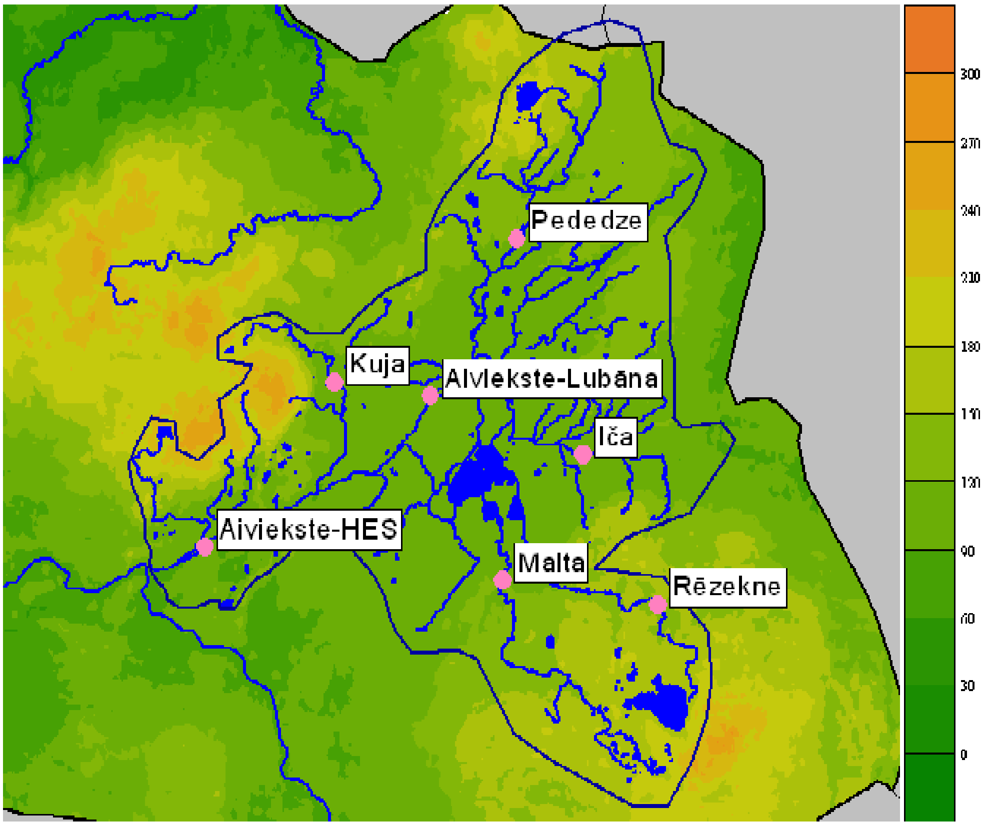


Fig. 8.6. The location of the hydrometric observation stations.

Aiviekste at Aiviekste HPP is the most downstream station which represents the whole catchment area 8660 km^2. The particular subbasins with different types of land use, river slope and also meteorological conditions are accounted by hydrometric stations Kuja @ Aizkuja (rather fast right tributary representing Vidzeme highland, catchment area 268 km^2), Pededze @ Litene (representing the River Pededze and northern part of the catchment, rich in forests, catchment area 978 km^2), Iča @ Kuderi (representing eastern part of the Lubāna depression, catchment area 674 km^2), Malta @ Viļāni and Rēzekne @ Griškāni (representing the agricultural Southeastern part of the catchment, catchment areas, respectively 782 km^2 and 545 km^2). The hydrometric station Aiviekste @ Lubāna is located in the central part of the basin (catchment area 7200 km^2). It characterizes the discharge downstream the confluence of the River Pededze and upstream the entrance of the Meirānu channel. The discharge measurements at these hydrometric stations from Zīverts (2000) were used to (1) select the characteristic three year period in this Chapter, (2) to calibrate the modeling results. The hydrometric stations are located rather far upstream on the tributaries. The particular tributaries with the available discharge time series (Pededze, Rēzekne, Malta, Iča, Kuja) cover only 36% of the catchment area, producing (on average) also 36% of the River Aiviekste run-off. Therefore the calibration of each particular tributary is important for the adjustment of the land-use dependent parameters, whilst the most of the river basin is accounted by the total, i.e. Aiviekste HPP hydrometric station.

Three different years (typical, wet and dry) were used for the model calibration, assuming the start of the Year on Jul-1 (beginning of summer) and the end of the Year on Jun-30 (assuming that the spring snow-melt flood is ended). The discharge data was analysed to reveal 3 consecutive years which fulfill these requirements. Such three different Years were selected from 1-Jul-1976 to 30-Jun-1980.

4. The daily ***meteorological data (precipitation and air temperature)*** for these three years were purchased from Latvian Environmental, Geological and Hydrometeorological Agency at three meteorological observation stations (see Fig. 8.6.): Zīlāni, Gulbene and Rēzekne. The interpolation of the meteorological data between these 3 locations gives a representative variability in the meteorological conditions over the catchment area of the River Aiviekste.

The summary of the meteorological data for 3 selected Years is presented in Table 8.1., and of the hydrometric observations in Table 8.2. for all three Years and all considered stations.

Table 8.1. Summary of the meteorological observations.

Station	Gulbene	Rēzekne	Zīlāni
T average, deg C	4.28	4.42	4.87
P average, mm	632	608	647
T, average, dry year	4.49	4.76	5.09
P, average, dry Year	477	451	518
T, average, typical year	4.43	4.50	5.06
P, average, typical Year	635	626	660
T, average, wet year	3.92	4.00	4.45
P, average, wet Year	785	747	762

The selected years have following variability (for Zīlāni station):

- Jul/76 to June/77 is a dry Year, P=142 $m^3 s^{-1}$ (or 518 mm, deviation -22%)
- Jul/77 to June/78 is an average Year, P=181 $m^3 s^{-1}$ (or 660 mm)
- Jul/78 to June/79 is a wet Year, P=209 $m^3 s^{-1}$ (or 762 mm, deviation +15%)

One may consider that there is a reasonable variation of both the annual precipitation (up to 15%, southeastern Rēzekne being the driest) and the annual mean air temperature (up to 0.6 °C, northern Gulbene being the coldest) in the catchment area of the River Aiviekste.

Let us consider the variability of run-off at the most downstream gauge Aiviekste HPP (basin area 8660 km^2). The run-off modulus at this station is 127 mm, 213 mm, and 334 mm or discharge at this gauge is, respectively, 25%, 32%, and 44% of the precipitation for three respective Years. The runoff modulus is lower during the dry years due to the relatively higher evaporation (high T, low e) and higher infiltration (low soil moisture, low groundwater level). The run-off modulus is higher for the wet years due to the lower evaporation (low T, high e) and lower infiltration (high soil moisture, high groundwater level, distinct spring snow-melt flood).

Table 8.2. Summary of the annual mean discharge ($m^3 s^{-1}$) at selected stations.

Station	Catchment km^2	Dry year 1976/77	Typical year 1977/78	Wet year 1978/79
Aiviekste HPP	8660.00	34.85	58.60	91.75
Aiviekste Lubâna	7200.00	24.18	42.57	62.81
Kuja	268.00	1.47	2.82	3.65
Pededze	978.00	4.67	7.24	12.95
Ičа	674.00	2.37	5.76	N/A
Rēzekne	505.00	1.49	3.37	5.06
Malta	782.00	2.71	6.14	8.29

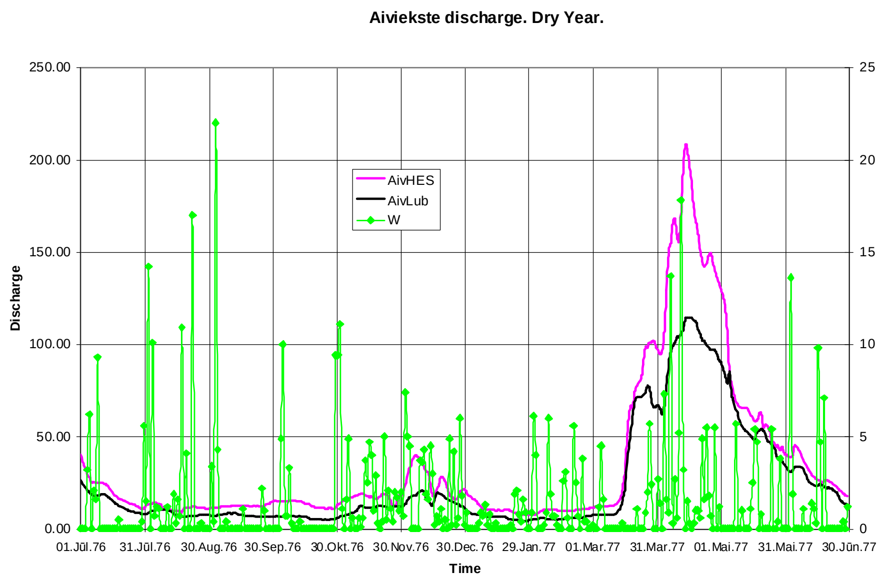


Fig. 8.7. Daily discharge at Aiviekste @ HPP, Aiviekste @ Lubāna, an precipitation for the dry year.

Discharge measurements at the Aiviekste stations and the precipitation for the dry year are shown in Fig. 8.7. Dry years are characteristic with the single snow-melt flood. No travel time of the flood signal may be distinguished. There is no immediate response of the precipitation signal in the discharge time-series.

Wet year is characterised by multiple rain events during the summer and prolonged rainfalls during the autumn. The latter results in the distinct autumn high-water. Still neither travel time of the flood signal may be distinguished nor there is an immediate response of the precipitation signal in the discharge time-series.

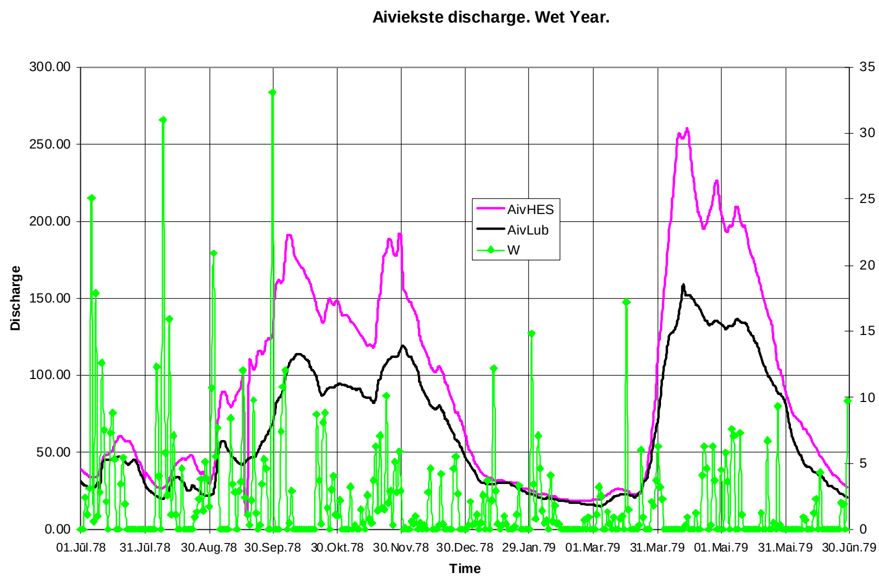


Fig. 8.8. Daily discharge at Aiviekste @ HPP, Aiviekste @ Lubāna, an precipitation for the wet year.

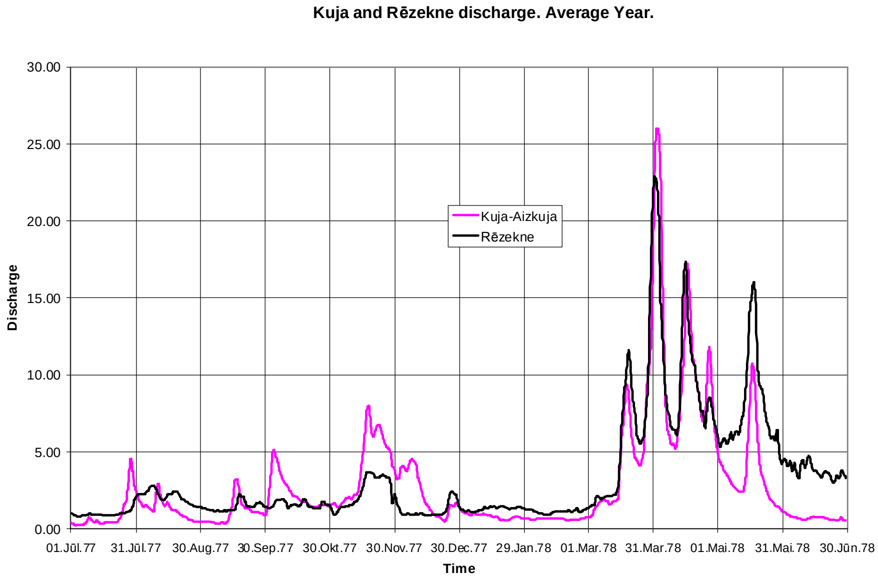


Fig. 8.9. Daily discharge at Kuja @ Aizkuja and Rēzekne @ Griškāni for the typical year.

There are reasonable differences in the discharge time-series for different subbasins (Fig. 8.9.), where Kuja and Rēzekne rivers are compared. Kuja subbasin has higher slope, whilst Rēzekne is a typical lowland river. Therefore response of the discharge on the precipitation events is much more distinct for Kuja. Comparison of the snow-melt events in both rivers indicates also some climatic variability in the Aiviekste basin.

The measurements in upstream (Pededze) and downstream (Aiviekstes HPP) stations are compared in Fig. 8.10. There is no delay in the precipitation or the snow-melt signal. However, the water retention is much higher in the downstream gauge due to the effect of the water storage in Lubāna Lake.

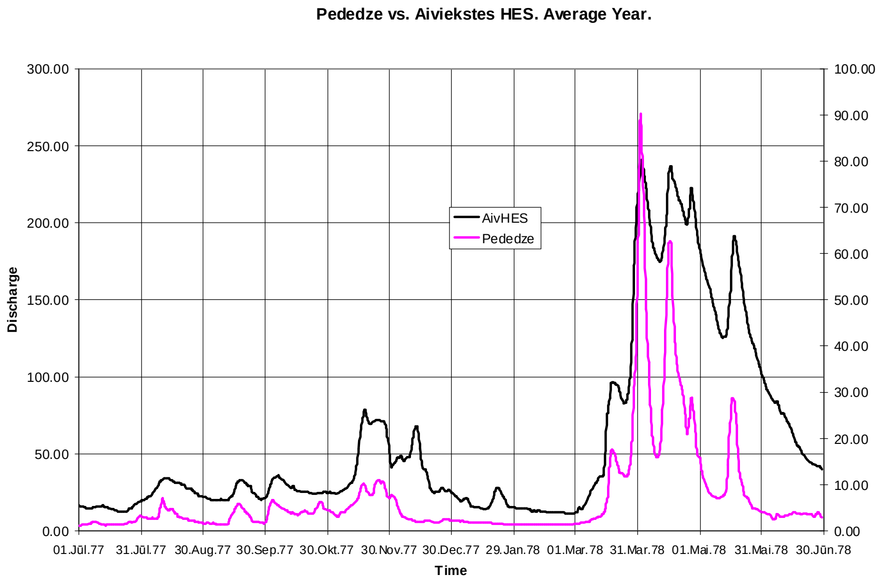


Fig. 8.10. Daily discharge at Aiviekste @ HPP and Pededze @ Litene for the typical year.

8.4. Model calibration

The model calibration was performed for the 3 Year period (from 1-Jul-1976 to 30-Jun-1979). The 2D interpolation of the daily meteorological parameters (precipitation, air temperature) from 3 observation stations (Fig. 8.5.) was used, whilst we assumed climatologic mean for the air humidity.

The goal of the calibration was in finding the set of model parameters (groundwater model parameters and the land-use dependent surface water run-off, evaporation, melting and infiltration parameters) which minimizes the deviation from the observed daily discharges in 7 hydrometric stations (Fig. 8.6.).

Each three year model calibration run was preceded by 90 years long "warm-up" period for stabilising the groundwater level at the quasi-periodic state and to avoid the initialization effects.

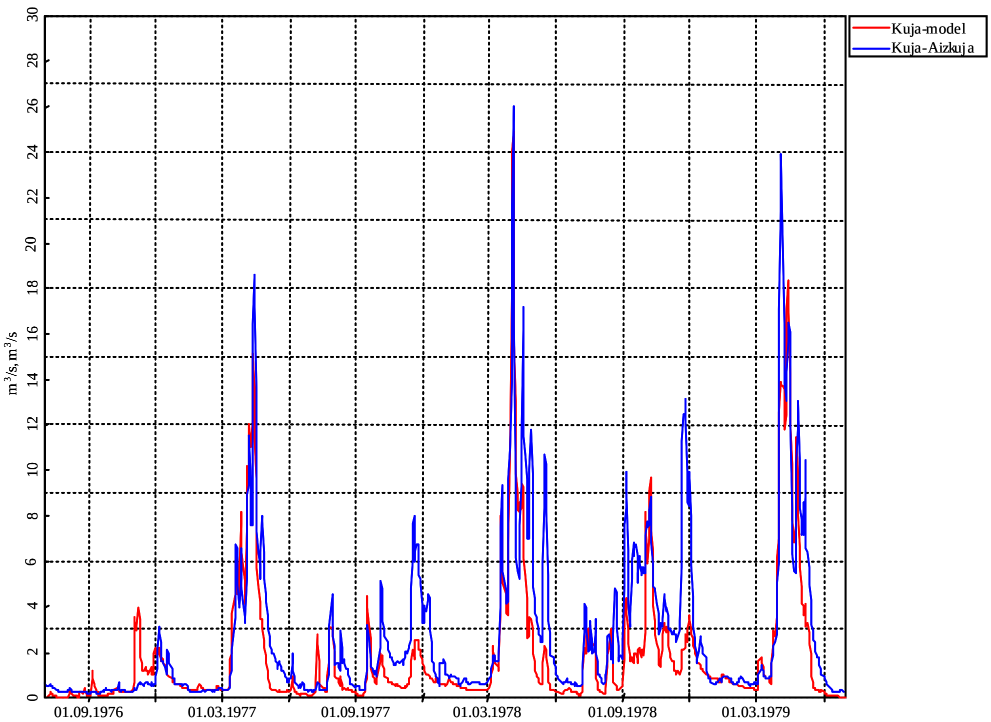


Fig. 8.11. Calculated vs. observed daily discharge for river Kuja @ Aizkuja.

The calibration results – a set of the model parameters is given in Table 3, whilst the calculated vs. observed discharges at 7 hydrometric stations are shown in Figs. 8.11–8.17. The summary of the observed and calculated runoff for the subbasins and the whole Aiviekste catchment area are given in Table 8.4.

The general features of the difference in the land use-dependent calibration parameters may be found in Table 8.3. Thus, forests have lower evaporation and snow-melt rate values, higher friction for overland flow and volume of intercepted water storage.

The agreement between the observed and modelled discharge time-series is reasonable for the small rivers (Figs. 8.11–8.15.). Generally, the high-water situations are underestimated in the model. At the same time both the observation quality and the accuracy of the catchment area may be questioned for the small hydrometric stations located rather far upstream from the rivers' entrance to larger water bodies.

Table 8.3. Calibration results – model parameters.

Parameter	Land use	Value
Hydraulic conductivity of soil K	All	10 m day^{-1}
Soil storativity Ss	All	0.25
Manning coefficient	Forest	4.5
Manning coefficient	Agricultural, swamps	4
Manning coefficient	Bushes	4.25
Manning coefficient	Artificial	1
$W_{intercepted}$	Forest	40 mm
$W_{intercepted}$	Agricultural	30 mm
$W_{intercepted}$	Bushes	35 mm
$W_{intercepted}$	Artificial, swamps	10 mm
V_{imin}	All	0.5 mm day^{-1}
V_{imax}	All but swamps	2.5 mm day^{-1}
V_{imax}	Swamps	1.5 mm day^{-1}
Evapotranspiration coeff. K_e	Agricultural, Swamps, Artificial	0.55 mm (day*mbar)$^{-1}$
Evapotranspiration coeff. K_e	Forests	0.50 mm (day*mbar)$^{-1}$
Evapotranspiration coeff. K_e	Bushes	0.52 mm (day*mbar)$^{-1}$
K_e-snow	Agricultural,Swamps, Artificial	0.14 mm (day*mbar)$^{-1}$
K_e-snow	Forests	0.10 mm (day*mbar)$^{-1}$
K_e-snow	Bushes	0.12 mm (day*mbar)$^{-1}$
Snow melt coefficient C_{meltB}	Agricultural, Swamps	4 mm (day*K)$^{-1}$
Snow melt coefficient C_{meltB}	Forests	2.5 mm (day*K)$^{-1}$
Snow melt coefficient C_{meltB}	Bushes	3 mm (day*K)$^{-1}$
Snow melt coefficient C_{meltB}	Artificial	5 mm (day*K)$^{-1}$
Reference temperature T_2	Agricultural, Swamps	0.2 ºC
Reference temperature T_2	Forests	1.0 ºC
Reference temperature T_2	Bushes	0.5 ºC
Reference temperature T_2	Artificial	0.0 ºC
$\Delta l_{surface}$	All	100 m

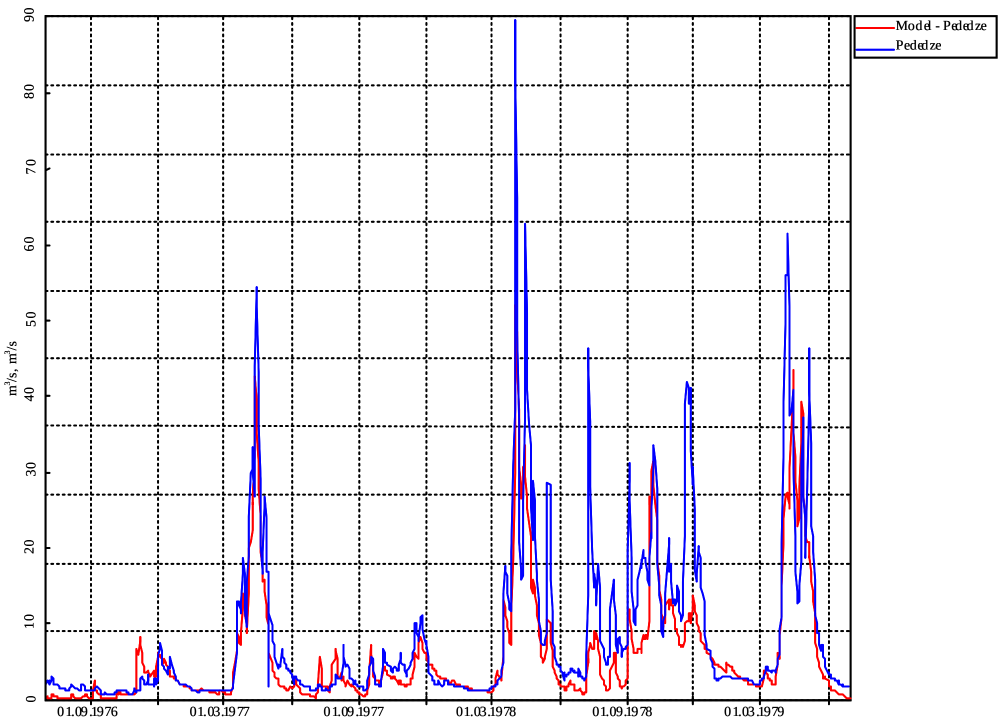


Fig. 8.12. Calculated vs. observed daily discharge for the Rriver Pededze @ Litene.

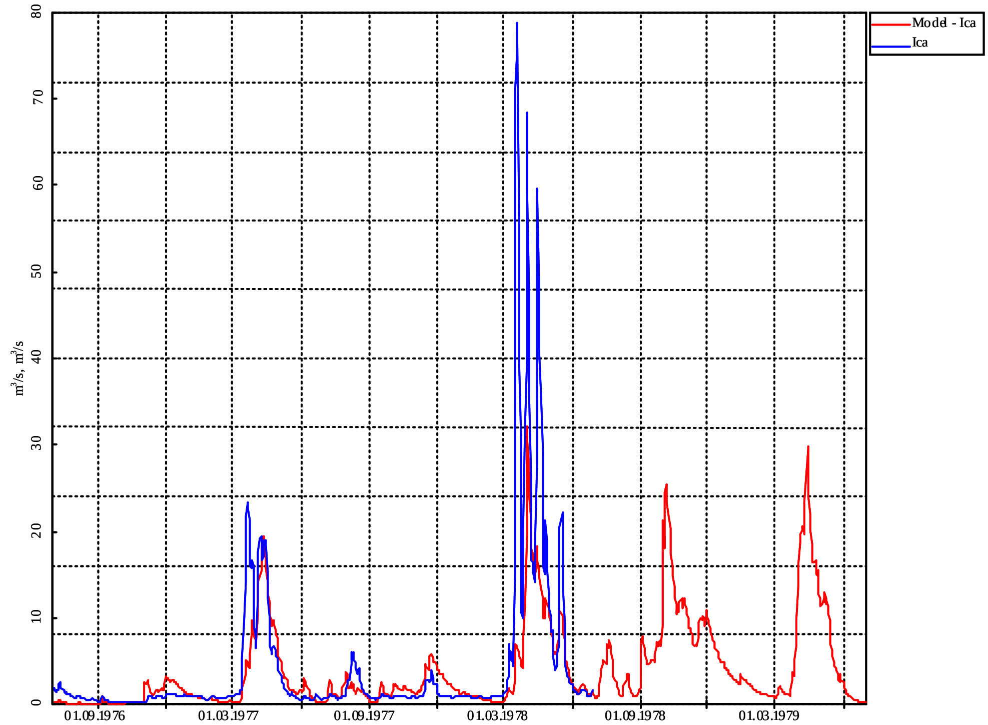


Fig. 8.13. Calculated vs. observed daily discharge for the River Ičа @ Kuderi.

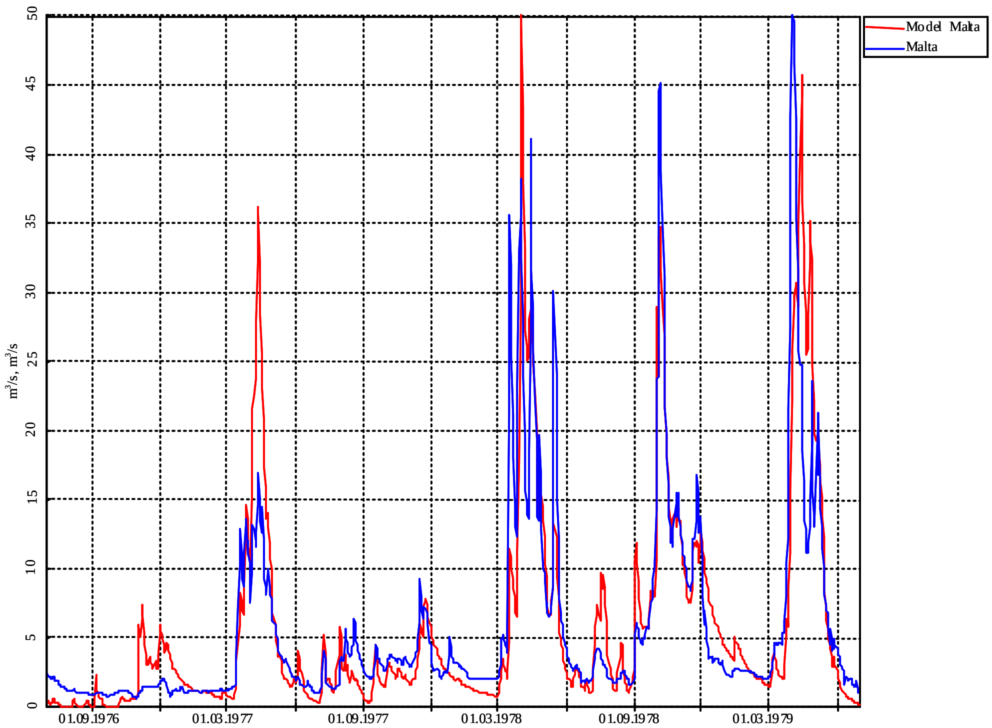


Fig. 8.14. Calculated vs. observed daily discharge for river Malta @ Viļāni.

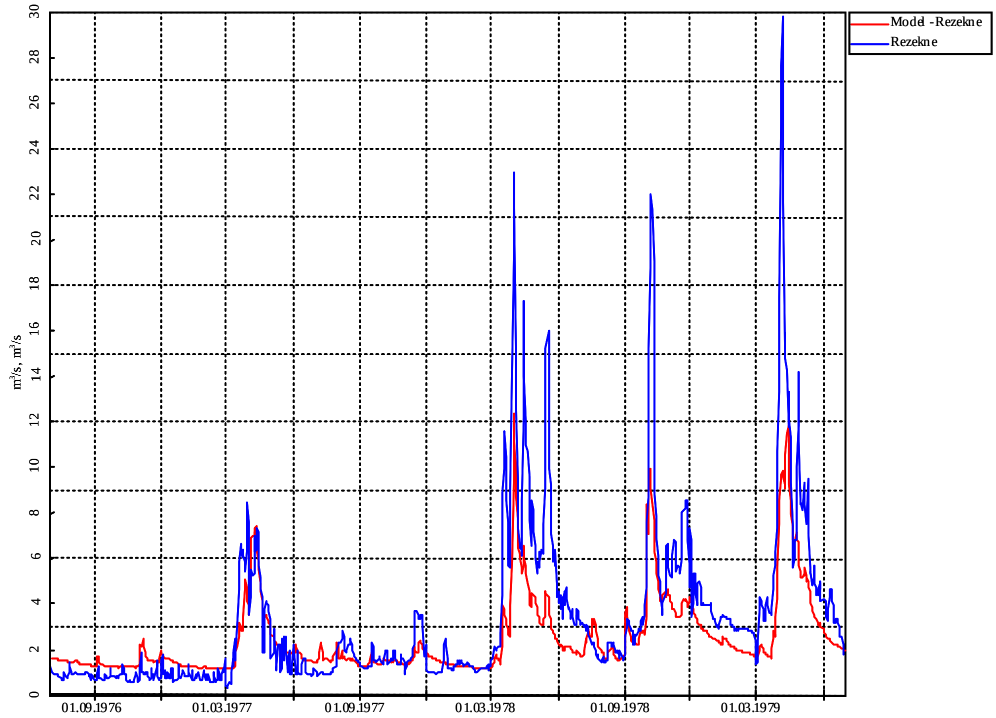


Fig. 8.15. Calculated vs. observed daily discharge for the River Rēzekne @ Griškāni.

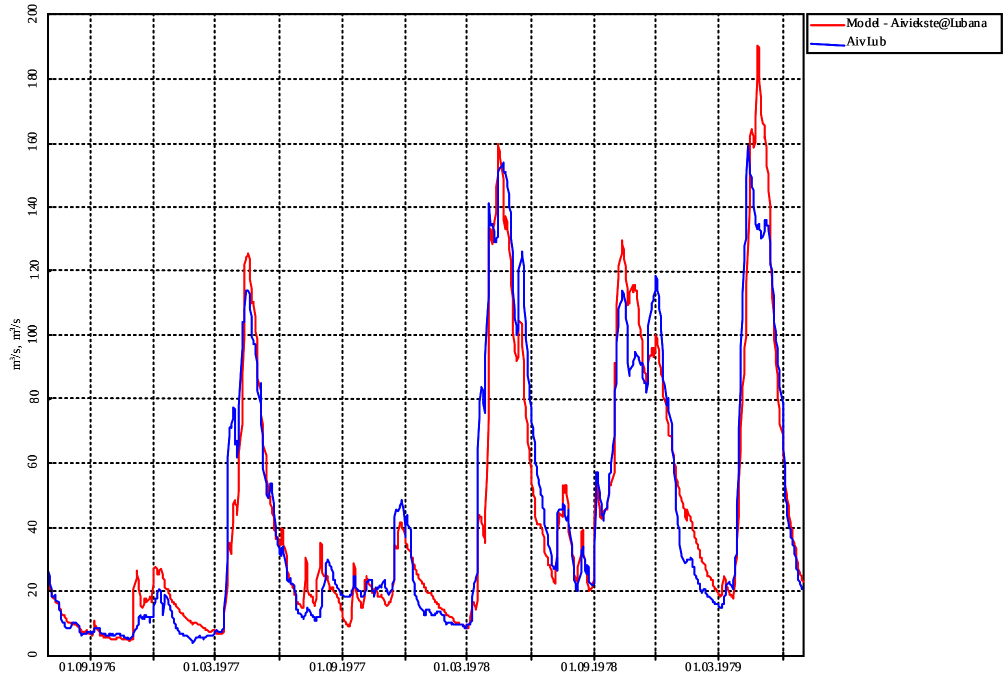


Fig. 8.16. Calculated vs. observed daily discharge for the River Aiviekste @ Lubāna.

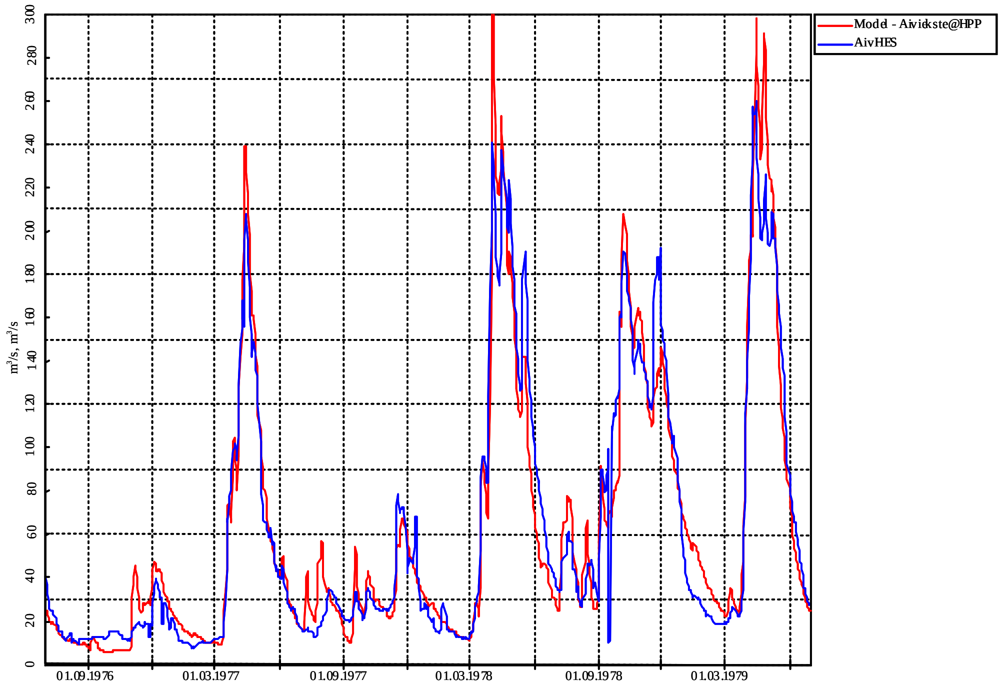


Fig. 8.17. Calculated vs. observed daily discharge for the River Aiviekste @ HPP.

The agreement between the calculated and observed discharge values of the River Aiviekste may be assessed as excellent (Figs. 8.14. – 8.15.). Model well represents both the high- and low- water situations qualitatively and quantitatively. The transitions (i.e. decrease of discharge after the rain or snow-melt events) is also rather accurate. The model slightly overestimates the high-water events at the Aiviekste HPP. This may be explained by the reduction of these peaks by the regulation of HPP reservoir level.

Table 8.4. Comparison of the mean observed and calculated discharge for different hydrometric stations.

No.	River	Discharge, observed $m^3\ s^{-1}$	Discharge, modelled $m^3\ s^{-1}$
1	Kuja @ Aizkuja	2.64	1.82
2	Pededze @ Litene	8.29	5.86
3	Ičа @ Kuderi	4.07	2.76
4	Malta @ Viļāni	5.71	5.77
5	Rēzekne @ Griškāni	3.30	2.48
6	Aiviekste @ Lubāna	43.19	43.25
7	Aiviekste @ HPP	61.73	62.60

The underestimation of the average runoff for small rivers (except Malta) and very good agreement for both Aiviekste stations can be seen also in Table 8.4.

8.5. Calculation results

The calculation results for the reference situation are presented and the calculations for three future scenarios are performed.

The climate change scenarious were used and extrapolated for 50 years period. The seasonal change of the average temperature and precipitation for these three (Low, Central and High) scenarios for 50 years is summarized in Table 8.5. We added the values of these data changes to the representative meteorological observations (1-Jul-1976 to 30-Jun-1978) to calculate the future run-off scenarios. All scenarios are related to the increase of temperature and precipitation, especially, during the winters.

The distribution of the groundwater level is very similar to the surface elevation (Fig. 8.18.), and it has no distinct seasonal variations. The distribution of the snow cover indicates the climatic variability in the Aiviekste River basin. See the correlation between the air temperature (°C) and the thickness of the snow cover (m) in the beginning of the winter in Fig. 8.19.

Table 8.5. Changes of the mean meteorological parameters for 50 years period. Low, Central and High scenarious.

Parameter/scenario	Spring(III-V)	Summer (VI-IX)	Autumn(X-XII)	Winter(I-II)	Annual
P / Low, %	+0.625	+1.25	+1.25	+2.1	+1.25
T / Low, °C	+0.5	+0.4	+0.5	+0.65	+0.5
P / Central, %	+2.5	+5.0	+5.0	+10.0	+5
T / Central, °C	+2.0	+1.5	+2.0	+3.0	+2.0
P / High, %	+3.75	+7.5	+7.5	+12.5	+7.5
T / High, °C	+3.0	+2.25	+3.0	+3.75	+3.0

Let us consider the modeling results for the reference (present) situation.

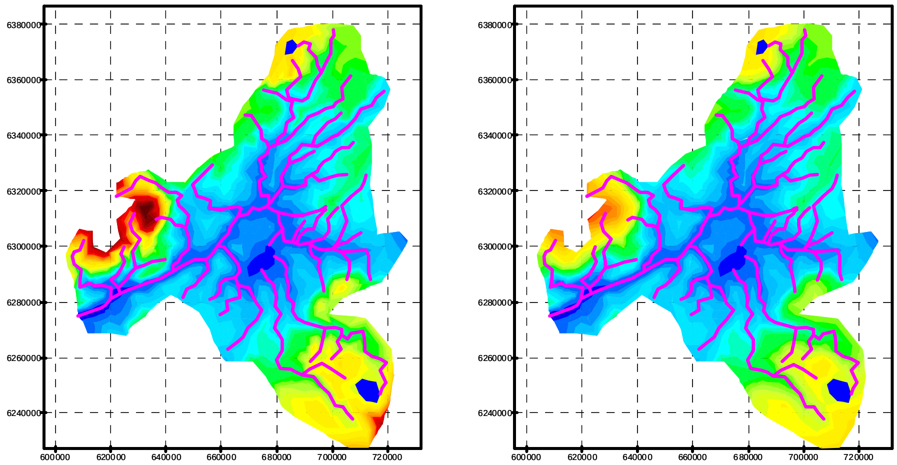


Fig. 8.18. Surface elevation (left) and the groundwater level (right).

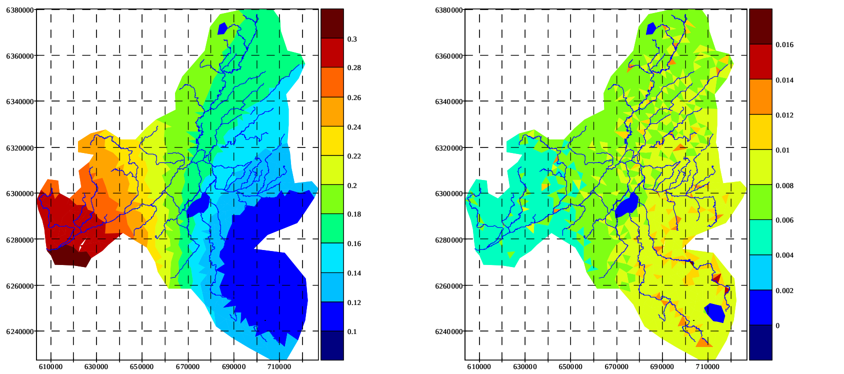


Fig. 8.19. Air temperature (left) and the thickness of the snow cover (right) in the beginning of winter (11-Dec-1976).

The calculation results for the scenarious of the climatic change are compared at the station Aiviekste @ HPP as the discharge time graphs for Reference vs. Low scenario (Fig. 8.20.), Low vs. Central scenario (Fig. 8.21.) and Central vs. High scenario (Fig. 8.22). The discharges for different seasons and all scenarious are summarised in Table 8.6.

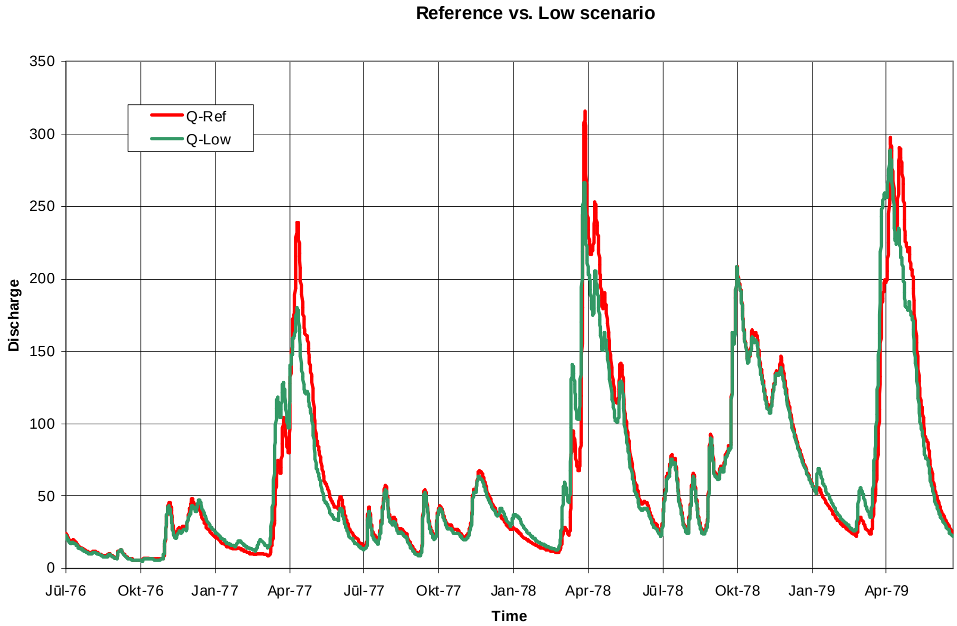


Fig. 8.20. Time series of the discharge of Aiviekste @ HPP for the reference and Low scenario.

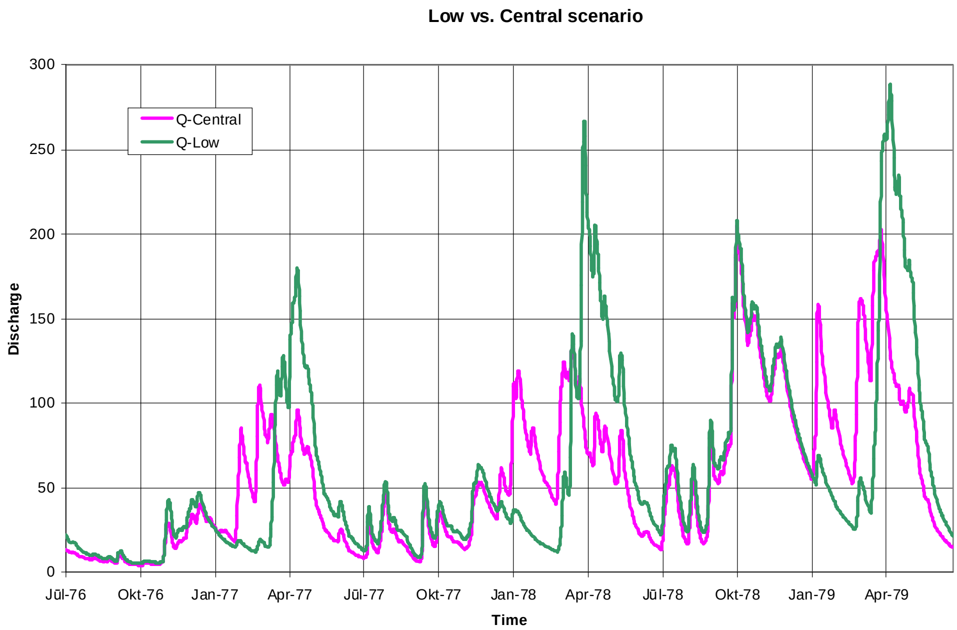


Fig. 8.21. Time series of the discharge of Aiviekste @ HPP for the Low and Central scenarious.

The implementation of the Low climatic change scenario causes lower accumulation of snow, and slightly reduces the maximums of the snow-melt-floods (Fig. 8.16.). Winter run-off increases by 17.5%, whilst spring runoff decreases by 3.5%. The yearly run-off decreases by 2.5% (Table 8.6.) due to the slightly higher air temperatures and less concentrated spring floods.

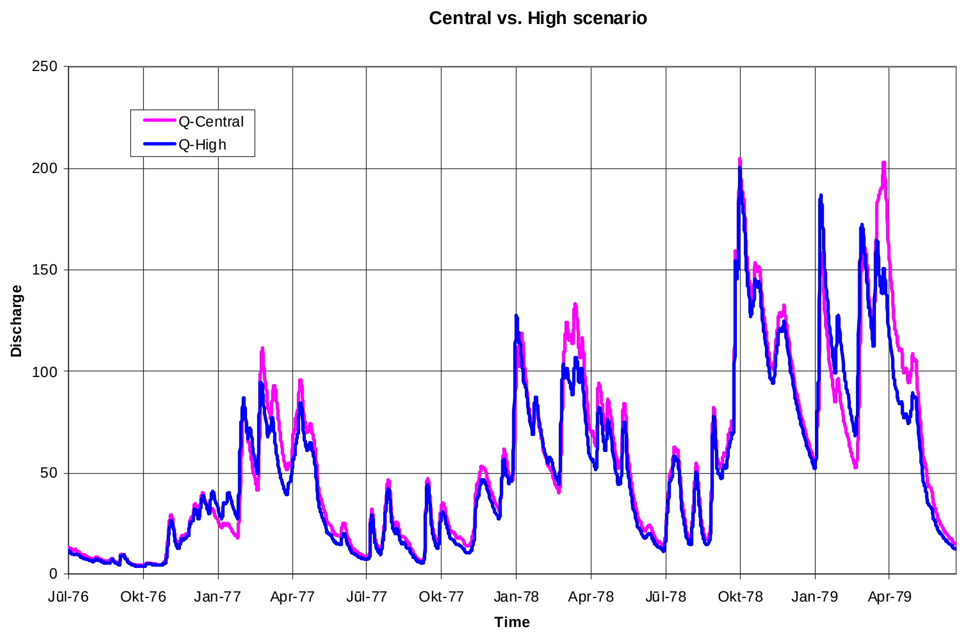


Fig. 8.22. Time series of the discharge of Aiviekste @ HPP for the Central and High scenarios.

Table 8.6. The mean seasonal discharge ($m^3 s^{-1}$) of the river Aiviekste @ HPP for 3 different climatic scenarios.

Scenario	I-II	III-V	VI-IX	X-XII	AVERAGE
Reference	24.5	123.3	33.4	65.1	62.6
Measured	17.9	120.5	35.7	65.5	61.7
Low	28.8	119.0	30.8	63.7	61.0
Central	69.0	87.5	23.1	59.2	55.8
High	77.9	74.1	20.3	55.5	52.0

The main qualitative change in the hydrology of the future scenarios occurs in transition between Low and Central scenarios (Fig. 8.21.). The increase of the winter air temperatures is a reason for multiple winter rainfalls (instead of snowfalls) causing the increase of the winter run-off more than two times, and the decrease of the spring runoff by one third. The summer run-off is generally lower due to the higher air temperature increases the evapotranspiration. The annual run-off in comparison with the reference situation decreases by 11%.

9 Conclusions

The complex transition period has diverse impact on processes both in society and environment. On the one hand, the environmental situation has been relatively improved due to recession in industrial and agricultural production. On the other hand, it is characterized by aggravation of human health and human environmental problems, indicating that social factors have affected public health and life quality. In the transition period it has been nearly impossible to overcome the heritage of the former period due to financial constraints and limitations: the formal improvement of environmental state has been achieved mostly by closing down inefficient enterprises. This heritage presents a huge obstacle, a burden to future development, that restricts restructuring of industry and agriculture, and hinders the general improvement of environmental situation.

So, the transition period poses new tasks for environmental policy. There is a need to develop an institutional and legal framework for the environmental protection system. It is necessary to improve decision-making and the implementation mechanism. Environmental policy in the transition period must look forward. It is necessary to change the traditional conservationist attitudes and the desire to forbid any development in the industrial production sphere into efficient treatment of existing problems and the prevention of new impacts. At present, the improvement of the environmental situation must be regarded as a timely manifestation of transition period which upon restructuring of production could again become worse. Environmental policy must be prepared to deal with these problems. International cooperation and aid in the area of environmental protection (which undoubtedly plays a very great role) in environmental policy formation should include the goals to increase implementation efficiency, regarding both technological and institutional aspects, and to develop the local learning process. However, human health, the human environment and life quality problems must be included in the agenda of environmental problems as their priorities.

Among major problems concerning environmental quality the loading to surface waters can be considered. As a tool to study the actual impacts on the water quality modeling can be used and so of utmost importance is development of regional modeling tools for local application. The mathematical model of the hydrology was developed and calibrated in this study. The calibrated model was applied for the modelling of the run-off from the catchment for the typical and climate change scenarios and it will be used to study human impacts on surface water quality.

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Kuvailulehti

Julkaisija	Pirkanmaan ympäristökeskus	Julkaisuaika Syyskuu 2005
Tekijä(t)	Tom Frisk, Māris Kļaviņš, Uldis Bethers, Ilga Kokorīte, Juris Seņņikovs, Valery Rodinov ja Ämer Bilaletdin	
Julkaisun nimi	Kuormitus Latviassa ja sen vaikutukset veden laatuun	
Julkaisun osat/ muut saman projektin tuottamat julkaisut		
Tiivistelmä	Ympäristöongelmat ovat yksi tärkeimpiä kysymyksiä valtioissa, joissa on erilainen taloudellinen tilanne ja sosiaalinen ja poliittinen systeemi. Eniten ollaan huolissaan ihmisten vaikutuksesta luontoon ja ympäristön laatuun. Yleinen käsitys on, että ympäristöongelmat ovat kaikkein akuutimpia Itä-Euroopan ja Baltian maissa sekä entisessä Neuvostoliitossa. Kuitenkin näiden maiden keskuudessa on suuria eroja riippuen mm. teollistumisen asteesta ja kulutettujen tavaroiden määrästä. Em. tekijöistä riippuen eri mailla on myös erilaiset asenteen ympäristöongelmiin ja niiden ratkaisemiseen. Tämän Suomalais-Latvialaisen yhteisprojektin päämäärä oli kehittää monitieteellinen näkemys niihin tekijöihin, jotka vaikuttavat veden laatuun sekä Latviassa että Itämeressä. Projekti pyrki yhdistämään analyysin Latvian sosioekonomisesta tilanteesta, todellisesta ihmisen aiheuttamasta kuormitusvaikutuksesta veden laatuun yhdessä ympäristönsuojelusysteemin kehityksen kanssa sekä vesiekosysteemien ja Itämereen tulevan kuormituksen mahdolliset vasteet. Todellisten vaikutusten tutkimiseen käytettiin hydrologista vedenlaatumallia. Mallilla simuloitiin valuntaa valuma-alueelta nykyisessä ilmastossa ja eri ilmastonmuutosskenaarioilla. Projektin toinen päämäärä oli koota yhteen olemassaoleva tieto ympäristön laadusta, ympäristönsuojelun kehityksestä viime vuosikymmeninä sekä kuinka historiallinen perintö ja yhteiskunnan uudistusprosessi on vaikuttanut ympäristöön ja kuinka nämä aktiviteetit voivat vaikuttaa kehitykseen tulevaisuudessa.	
Asiasanat	vedenlaatu, ihmisen vaikutus, sosioekonomia, mallinnus	
Julkaisusarjan nimi ja numero	Suomen ympäristö 793	
Julkaisun teema	Ympäristönsuojelu	
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Title of publication	Loading from Latvia and its impact on water quality	
Parts of publication/ other project publications		
Abstract	Environmental problems now are among the most important questions for states of different stages of economical development, social and political systems. The most often expressed view concerns the recognition or understanding of human impacts on nature and environmental quality in cities. Commonly it has been assumed that environmental problems are especially urgent for East European, Baltic countries and the former Soviet Union. However, there exist major differences among different states in this region, depending on the level of industrialization, the amount of resources consumed and some other factors. Depending on these factors, as well as, on the way of development, different attitudes towards environmental issues and the ways of solving them in relevant economical and political situation have been pointed out. The aim of the joint Finnish-Latvian project was to develop an interdisciplinary view on the factors affecting water quality in Latvia, but also influencing the Baltic Sea. Project tried to integrate not only analysis of socio-economic situation in Latvia and actual human impacts on water quality with process of development of environmental protection system, but also possible responses of aquatic systems and loadings to the Baltic Sea focusing on the influences coming from cities of Latvia. As a tool to study the actual impacts on the water quality modeling can be used and so of utmost importance is development of regional modeling tools for local application. The mathematical model of the hydrology was developed and calibrated in this study. The calibrated model was applied for the modelling of the run-off from the catchment for the typical and climate change scenarios and it will be used to study human impacts on surface water quality. Another goal of this project was to summarize existing information on environmental quality, environmental protection system in Latvia during last decades – transition period and on how the historical heritage and the restructuring process in society has influenced environment and how these activities can influence the development in future.	
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ENVIRONMENTAL PROTECTION

Loading from Latvia and its impact on water quality

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